THE INSTITUTION OF ENGINEERS, AUSTRALIA

The Australian Historic Engineering Plaquing Programme

COMMEMORATIVE PLAQUE NOMINATION

NATIONAL ENGINEERING LANDMARK

NARROWS BRIDGE

Perth, Western Australia

Engineering Heritage Panel
Western Australia Division
The Institution of Engineers, Australia

August 1999

APPLICATION FORM

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Date: 31st August 1999
From Engineering Heritage Panel
Institution of Engineers, Aust.
W.A. Division

The following work is nominated for a:

- National Engineering Landmark
- ~~Historic Engineering Marker~~

(delete as appropriate)

Name of work -	Narrows Bridge
Location, including address and map grid reference if a fixed work -	Over the Swan River at the Narrows Between Point Lewis, Central Perth and Point Belches, South Perth
Owner -	Commissioner of Main Roads Main Roads Western Australia
The owner has been advised of the nomination of the work and has indicated (attach a copy of letter if available) -	Yes - See copies of letters at Appendix 1
Access to site -	Regional Dual Use Path system for pedestrians and bicycles crosses bridge. Also car parks are located adjacent to each abutment.
Future care and maintenance of the work -	Assured - by Main Roads Western Australia
Name of sponsor -	Main Roads Western Australia
For a NEL, is an information plaque required?	Yes

Chairperson of Nominating Committee: Mr Ralph Moore

Chairperson of Division Heritage Committee/Panel: Mr Bruce James

ADDITIONAL SUPPORTING INFORMATION

Name -	Narrows Bridge
Statement of Significance	The Narrows Bridge, a five-span precast, prestressed concrete, continuous beam highway bridge over the Swan River, has engineering heritage significance for the following reasons:

- It was the crucial element in and the first manifestation of the implementation of the 1955 Stephenson-Hepburn Report "Plan for the Metropolitan Region, Perth and Fremantle" which changed the direction of development of metropolitan Perth from an east-west axis to a north-south axis.

- It was the largest precast, prestressed concrete continuous beam bridge in the world at its opening.

- Its centre span of 320ft (335m) was the longest of its type in Australia and the bridge was one of the largest of its type in the world at its opening.

- It was the first bridge in Australia to use a segmental method of construction.

- It was the first bridge in Australia to use external pre-stressing cables allowing a lighter web construction.

- It represents a very early example of the Udall-Gifford pre-stressing system.

- It was the first bridge in Australia to use Gambia piles.

- It was the first major public work in Western Australia since the end of the Second World War to be constructed by contract.

- Its engineering design and construction met the stringent requirements of the State Government of the day for an aesthetic, slim-line bridge in this critical location.

- Its slim-line appearance has a very high aesthetic value in the visual profile of the Cities of Perth and

South Perth, Kings Park, Mount Eliza, and the Swan River.

- It successfully overcame the major geotechnical problem of creating a suitable bridge foundation in very complicated ground conditions with a great depth of laterally moving soils.
- It highlighted the need for research to solve the problem of defining the ultimate behaviour of pre-stressed concrete beams subject to combined bending and shear at the supports.

Year of Construction or Manufacture

Commenced construction March 1957.
Completed construction September 1959.
Official opening 13 November 1959.

Physical Condition

The Narrows Bridge is in a sound condition having been continually maintained and upgraded since it first went into operation in 1959. However, there is evidence of some superficial deterioration to the presentation of the Bridge.

(Attachment 2, pp 35 and 39).
(Attachment 3 "Assessment Documentation", p 3).

Note:
It should be noted that Attachment 2 refers to the planned widening of the Narrows Bridge. This plan has since been revised and the capacity of the river crossing will now be increased by the construction of a second bridge adjacent to and downstream of the existing bridge. The new bridge is to have the same architectural appearance and aesthetics as the existing bridge. The contract commenced in June 1999 and is to be completed by the end of 2000.

Engineering Heritage Significance:

Technological/scientific value -

The Narrows Bridge is a precast, segmental, prestressed post-tensioned concrete bridge with a length of 335m (1100ft) in five spans, a central span of 97.5m (320ft) and 2 flanking spans each side of 70m (230ft) and 49m (160 ft). It is designed to be fully continuous under live load. It is anchored at the north abutment and all expansion movement is provided for

at the south abutment.

At the time of construction, the central span of 97.5m (320ft) was the longest of its type in Australia and the precast pre-stressed concrete continuous beam bridge the largest in the world. (Attachment 8, p 364).

The bridge is founded on 180 long piles which support abutments and piers of reinforced concrete. The piers support reinforced concrete rocking columns which in turn carry the deck structure of prestressed concrete.

The piles adopted are of a type invented by Mr G A Maunsell and are known as "Gambia" piles from the fact that he first used them in Gambia, Africa. They consist of 31.25 inch outside diameter steel tubes with 0.125 inch thick walls terminating in a conical steel toe. Reinforced concrete was placed in the toe of each pile for a depth of 15 feet prior to driving, which was carried out by means of a 10-ton drop hammer operating inside the pile and delivering its blows on a removable driving helmet lying on the concrete in the toe. Extensions to the tubes were welded on as required during driving.

After driving, the steel tubes were filled with reinforced concrete, the design being such that reliance is placed only upon the reinforced concrete core; thus corrosion of the outer steel tube is not a danger to the structure.

The piles for the north shore pier were of a modified design to allow for possible movements in the reclaimed ground through which they were driven. In this case, the upper 60 feet of the pile consisted of a precast reinforced concrete column placed inside a 48 inch diameter steel shell after driving. The space between the two permits deflection with ground movement of the steel shell which is weak in bending, without transmission of the deflection to the precast concrete column supporting the bridge. (Attachment 8, p 365).

It was the first bridge in Australia to use segmental construction, the first to use these Gambia piles, and the first to use external prestressing cables which allowed a lighter web structure. The Narrows Bridge also represents a very early example of the Udall-Gifford prestressing system. (Attachment 8, p 365).

Other unusual features included vertical shear cables, the method of casting the precast concrete segments and the method of obtaining continuity. (Attachment 8, p 366).

Attachment 1 provides a brief description of the Narrows Bridge structure and its statistics and also photographs of the various stages of the project from the original Narrows before construction to the finished bridge at its opening on 13 November 1959.

The Heritage Council of Western Australia has entered the Narrows Bridge on the Register of Heritage Places on a permanent basis, pursuant to Section 51 of the Heritage of Western Australia Act 1990. (Attachment 3 - letter dated 23 April 1999 including a copy of Government Gazette, W.A. 23 April 1999, p 1727).

The Institution of Civil Engineers, October 1961, provides a fully detailed description of the Narrows Bridge. (Attachment 4 - Paper 6498). (Attachment 5 - Discussion Paper 6498). (Attachments 7, 8 and 9 provide further information).

Historical Value -

The Heritage Council of Western Australia has entered the Narrows Bridge on the Register of Heritage Places on a permanent basis, pursuant to Section 51 of the Heritage of Western Australia Act 1990. (Attachment 3 - letter dated 23 April 1999 including a copy of Government Gazette, W.A. 23 April 1999, p 1727).

The Narrows Bridge was the first major public work in Western Australia to be undertaken by contract after the Second World War.

The Narrows Bridge was the first bridge in Australia to use segmental construction.

It was the first bridge in Australia to use Gambia piles.

It was also the first bridge in Australia to use external prestressing cables which allowed lighter web structures.

Social Value -

The Narrows Bridge was the crucial element in and first manifestation of the implementation of the 1955 Stephenson - Hepburn Report "Plan for the Metropolitan Region, Perth and Fremantle". The Plan later became the Metropolitan Region Scheme which

was enacted in legislation in 1963 and has guided the development of Perth ever since. It was the realisation of plans which had been discussed from the 1840s to bridge this narrow neck of the Swan River.

(Attachment 2, p.35).

(Attachment 3, "Assessment Documentation" p.2).

(Attachments 6, 7, 8 and 9).

Landscape or townscape value -

The Bridge displays landmark values in the context of Perth Water and the river beyond and provides vistas downstream and eastwards to the Darling Ranges.

The same visual resolution is apparent during the day and at night time in the context of an illuminated City and Bridge.

The slim profile of Narrows Bridge displays strong aesthetic characteristics.

(Attachment 3, "Assessment Documentation" p 1).

The first requirement of the design of the bridge was that it should be of good appearance, and worthy of its beautiful setting.

(Attachment 4, p 42).
(Attachment 5, p 114).
(Attachment 8, p 364).

Rarity -

The Narrows Bridge is not rare as a prestressed concrete structure of today. However, the form of the structure in pre-stressed concrete was innovative in bridge design in Western Australia in the 1950s. It displays the characteristics of a specific engineering design method. The structure is relevant for its continuous use from 1959, notwithstanding the substantial changes which have occurred in traffic volumes and loadings during that time.

(Attachment 2, pp 33 and 35).

Representativeness -

The Narrows Bridge demonstrates the characteristic slim profile and structural form of prestressed concrete bridge design which developed in the 1950s. The structure is representative of the development of the Metropolitan Region Scheme of Perth and the Traffic System which evolved as a result of that Scheme.

(Attachment 2, p 35).
(Attachment 3, "Assessment Documentation", p 3).

Contribution to the nation or Region -

The Narrows Bridge was the crucial element in and first manifestation of the implementation of the 1955 Stephenson-Hepburn Report "Plan for the Metropolitan Region, Perth and Fremantle", which Plan later became the Metropolitan Region Scheme after enactment by legislation in October 1963.

The Narrows Bridge was the initial focal element that enabled the development of Metropolitan Perth to change from an East-West axis to a North-South axis.

Its significance to the development of Metropolitan Perth in 1959 is very similar to the significance of Sydney Harbour Bridge in the development of Metropolitan Sydney in 1932.

The Narrows Bridge is a vital link in the Perth Metropolitan Region road network. Its importance in this regard cannot be overemphasized.

Contribution of engineering -

From a structural and geotechnical viewpoint, the Narrows Bridge was of a national and international importance in the development of prestressed concrete bridging and cast in situ reinforced concrete piles in driven casings.

The Narrows Bridge was the first bridge in Australia to use segmental construction.

It was the first bridge in Australia to use Gambia piles.

It was also the first bridge in australia to use external prestressing cables which allowed lighter web structures. See also "Technological scientific value".

"Although a large number of continuous and cantilever bridges had been built, there was at the time of the design, no published information on the ultimate behaviour of prestressed concrete beams subject to combined bending and shear." Because of the lack of information on this subject the designers considered that it would be prudent to check their assumptions by testing a scale model. The purpose of the test on a model of the main deck beam was to obtain information on:

(a) the efficiency of the method of attaching the cables to the beam webs by means of mild-steel shear bars;
(b) the strength of the beam in resisting combined bending and shear at the support and
(c) the effect on the behaviour of the beam, of the vertical mortar joints between segments and the horizontal construction joints between lifts of concrete.

(Attachment 4, pp 57 and 77).

It represents a very early example of the Udall-Gifford prestressing system.

(Attachments 4, 5, 7, 8 and 9).

Persons associated with the work -

J.D. Leach, BE MIE Aust
Commissioner of Main Roads

E.W.C. Godfrey, BCE, MIE Aust
Liaison Engineer (Main Roads Department)

J.G. Marsh, BE MIE Aust
Engineer (Main Roads Department)

J.W. Baxter, BSc MICE
Partner, G. Maunsell and Partners, Consulting Engineers, (UK)

E.M. Birkett, BSc, AMICE, AMIE (Aust)
Partner, G. Maunsell and Partners, Consulting Engineers, (UK)

E.W.H. Gifford, BSc, MICE
Senior Partner, EWH Gifford and Partners, Consulting Engineers, (UK)

Sir William Holford
Sir William Holford and Partners, Consulting Architects

J.O. Clough, DCM
J O Clough & Son, Perth (now Clough Engineering)

W.H. Clough, B.E. MscE AO OBE MIEAust
J.O. Clough and Son, Perth (now Clough Engineering)

L.O. Nilsen
Engineer, Christiani and Nielsen
Copenhagen, Denmark

T.G. Bingham - Resident Engineer,
G. Maunsell and Partners, Consulting Engineers

Integrity -	The Narrows Bridge has a high degree of integrity as it is intact with its cultural value being maintained throughout its relatively short history and its importance as an element in the landscape of the city being visually apparent. (Attachment 2, p 36). (Attachment 3, "Assessment Documentation" p 3).
Authenticity -	The Narrows Bridge has a high degree of authenticity as it survives with only minor changes to the original structure, reflecting the changing needs of the Perth Traffic System. (Attachment 2, p 36). (Attachment 3, "Assessment Documentation" p 3).
Comparable works (a) in Australia (b) Overseas	The degree of significance of the construction of the Narrows Bridge in 1959 to the development of Metropolitan Perth is comparable to the construction of the Sydney Harbour Bridge in 1932 and its significance to the development of Metropolitan Sydney, NSW.
Statement of significance, its location in the supporting documentation -	The Narrows Bridge has been judged as having a high degree of heritage significance by Mr Ron Boddicoat, architect, in his Conservation Plan of June 1998 and by the Heritage Council of Western Australia in their Registration Documentation of 23 April 1999. (Attachment 2, pp 33-38). (Attachment 3, pp 1-4). Main Roads Western Australia Bridge No.953 being part of the Port of Perth and Perth Lot 921, being part of Crown Reserve 37594 and being part of the land comprised in Crown Land Record Volume 3043 Folio 251 and Perth lot 920, being part of Crown Reserve 33804 and being part of the land comprised in Crown Land Record Volume 3040 Folio 55. (Attachment 3, Government Gazette, WA 23 April 1999 p 1727, and Heritage Council WA, Register of Heritage Places, Permanent Entry p 1).

Citation (70 words is optimum) - National Engineering Landmark

(Alternative 1)

Narrows Bridge

This five-span bridge, designed by G Maunsell & Partners and built by Christiani & Nielsen and J O Clough & Son for the Main Roads Department, Western Australia was the crucial element of the 1955 Stephenson-Hepburn Plan (later The Metropolitan Region Scheme) which re-shaped the development of Perth.

It was the first bridge in Australia to use precast, segmental construction, Gambia piles and external prestressing cables to allow lighter I-section deck beams.

At its opening in 1959 it was the largest precast, prestressed concrete, continuous beam bridge in existence and its 97.5m central span the longest of its type in Australia.

Dedicated by

The Institution of Engineers, Australia and the
Commissioner of Main Roads, Western Australia, November 1999.

(Alternative 2)

Narrows Bridge

This five-span bridge, designed by G Maunsell & Partners and built by Christiani & Nielsen and J O Clough & Son for the Main Roads Department, Western Australia was the crucial element of the 1955 Stephenson-Hepburn Plan (later the Metropolitan Region Scheme) which re-shaped the development of Perth.

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It was the crucial element of the 1955 Stephenson-Hepburn Plan (later the Metropolitan Region Scheme) which re-shaped the development of Perth.

Dedicated by

The Institution of Engineers, Australia and the
Commissioner of Main Roads, Western Australia, November 1999.

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APPENDIX 1

ENGINEERING HERITAGE PANEL.

The Institution of Engineers, Australia

WESTERN AUSTRALIA DIVISION

5th April 1999.

Mr Greg Martin,
Commissioner, Main Roads WA,
P.O.Box 6202,
EAST PERTH. 6892.

Historic Engineering Plaquing Programme.

Dear Mr Martin,

In 1984, the Institution of Engineers, Australia, established the Australian Engineering Plaquing Programme to acknowledge past engineering achievements and to draw community attention to the significant contributions they have made to society and to the engineers responsible for such works. The programme fosters the pride of the general public and the engineering profession in such works.

To date, in this State, Fremantle Harbour, the Kalgoorlie Pipe Line, the Albany Forts, the Applecross Wireless Station, the Rottnest Lighthouse and the Canning Dam have all been recognised in this way.

Currently, members of the Engineering Heritage Panel feel that two projects relating to roads should now be considered.

The first one is the Narrows Bridge, the opening of which will be celebrating its fortieth anniversary in November of this year.

The second project is the work done by a number of engineers, including Digby Leach, in perfecting the use of stabilized sand for major road construction work in this State. I gather that there is a section of road still in use in the vicinity of Lancelin that was the first to be constructed using this technology.

This letter is therefore to seek your agreement for the Institution to put forward these two nominations and that your Department would be prepared to maintain the plaques and allow for public access to view them.

Enclosed, is a Guide that details the process of submitting nominations and the final unveiling ceremony. The Institution will supply the plaques at no cost to your Department, and arrange the mailing out of the invitations. However, we would like some assistance in the preparation of the documentation for the nominations and towards the cost of the ceremonial arrangements.

Currently, we would like to unveil the Lancelin plaque during the 1999 Engineering Week, being the first week in September, and unveil the Narrows Bridge Plaque on Friday 12th November 1999.

We look forward to your approval and support for these nominations.

Yours sincerely,

B.J.

Bruce James,
Chairman,
Engineering Heritage Panel.

IEH90405.

2 4 JUN 1999

Enquiries:
Our Ref: 31-10545 cc 31-726V13 (00004257.cmr)
Your Ref:

MAIN ROADS
Western Australia

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Mr B James
Chairman
Engineering Heritage Panel
Institution of Engineers
712 Murray Street
WEST PERTH WA 6005

Dear Mr James

HISTORIC ENGINEERING PLAQUE PROGRAM

Thank you for your letter outlining the planned commemoration ceremonies for the 40th anniversary of the Narrows Bridge and the stabilised sand system used in the original construction of the Perth-Lancelin Road.

As you have pointed out, each project has interesting engineering components in the original planning and construction, and these are worth conveying to the general public.

Main Roads would be honoured to participate and contribute to these worthwhile projects.

Both yourself and Richard Usher have been in contact with our Manager Public Affairs, Dean Roberts, on 9323 4638 and I ask that you involve him in your planning so that he can assist on Main Roads behalf.

I wish you well in your endeavours.

Yours faithfully

GMartin

Greg Martin
ACTING COMMISSIONER OF MAIN ROADS
2 4 JUN 1999

ATTACHMENTS

ATTACHMENT 1	-	Brief description of the Narrows Bridge structure, bridge statistics and photographs showing stages of construction from original Narrows (no bridge) to the finished bridge at its opening on November 13 1959.
ATTACHMENT 2	-	Assessment of Significance, pp 1-41, Narrows Bridge Conservation Plan, prepared for Main Roads Western Australia by R Bodycoat, (June 1998).
ATTACHMENT 3	-	Heritage Council of WA letter dated April 23 1999 re permanent entry of Narrows Bridge on Register of Heritage Places.
ATTACHMENT 4	-	J W Baxter, E M Birkett, E W H Gifford "The Narrows Bridge, Perth, Western Australia". Paper No.6498, Institution of Civil Engineers (October 1961).
ATTACHMENT 5	-	Discussion on Paper No.6498 "The Narrows Bridge, Perth, Western Australia". Institution of Civil Engineers, (October 1961).
ATTACHMENT 6	-	"Official Opening" - The Opening Ceremony booklet produced by the Government of Western Australia (November 13 1959)
ATTACHMENT 7	-	" A Bridge is Built" - An historical record of the building of the Narrows Bridge, (November 1959).
ATTACHMENT 8	-	"Narrows Bridge, Perth", Roads and Road Construction, (December 1959), pp 364-367.
ATTACHMENT 9	-	Narrows Bridge, Western Roads, November 1984, Vol.9 No.4.

Acknowledgement

The Engineering Heritage Panel of The Institution of Engineers, Australia Western Australian Division gratefully acknowledges the Commissioner of Main Roads' kind permission to reproduce in this nomination extracts from the Narrows Bridge Conservation Plan prepared for Main Roads Western Australia by R. Bodycoat (June 1998).

ATTACHMENT 1

NARROWS BRIDGE

Brief Description of Bridge Structure, Bridge Statistics and

Photos showing

Stages of Construction

From Original Narrows (no bridge)

To

Finished Bridge 13 November 1959

The Narrows Bridge

PERTH, WESTERN AUSTRALIA

INTRODUCTION

The construction of the Narrows Bridge followed discussions between the Town Planning Consultant and the Commissioner of Main Roads in 1953.

Site investigations, which included surveys and test borings, were undertaken by the Main Roads Department at an early date thereafter, and in September, 1955, following investigations overseas by the Department's Bridge Engineer, Maunsell and Partners of London were appointed as Consultants to the project. The Consultants exercised full control of the work, including the preparation of all documents, plans and site supervision.

The Contract, awarded under tender, was placed with Christiani and Nielsen of Denmark in association with J. O. Clough and Son of Perth on 12th March, 1957.

The bridge reached substantial completion in September, 1959, and was opened to traffic on 13th November, 1959.

THE BRIDGE STRUCTURE

Description.—The superstructure in prestressed concrete embraces eight lines of I beams, the elements of which were cast on the shore, transported and assembled on temporary timber piling and trestling in the river. Structural union was effected by post-tensioned strands placed externally to and symmetrically about the webs of the beams and anchored off at suitably placed anchor blocks.

Each pier consists of four triangular shaped columns. Each column carries two beams.

The columns are supported on groups of "Gambia" piles through the medium of the pile cap.

The Gambia piles consist of a hollow steel casing adapted through 15 feet of toe concrete cast in the casing to driving internally by a 10-ton cylindrical hammer. As driving proceeds the casing is extended by welding and subsequently filled with reinforced concrete.

Modifications were required at the North Shore pier due to anticipated small movements of the upper layers of sand in the area and made apparent during construction. To permit this movement without causing a stress in the supporting piles a modified form of pile casing was used. This casing had an enlarged top section in which precast reinforced concrete piles were placed eccentrically in the casing and bonded into reinforced concrete at the bottom.

Each abutment consists of a vertical facing wall supported on Gambia piles and joined to walls which slope downwards and backwards from the facing wall. These sloping walls carry a slab from the top of the abutment wall to ground level where they in turn are supported on Gambia piles. The slab supports the earth fill behind the abutment.

Another lateral wall carried down in a trench below ground level is in structural union with the sloping walls to form a buttress against longitudinal thrust.

The superstructure of the bridge is structurally continuous over its full length, being "fixed" at the north end and supported on rollers at the south end.

Longitudinal movement of the superstructure over the piers due to any induced change of length is accommodated by allowing the pier column to act as a roller the diameter of which equals the height of the column. Suitably shaped stainless steel bearings are provided at the top and bottom of the column for this purpose. In addition, lateral movement at the base of three columns is provided at each pier.

For the purpose of permitting the longitudinal stressing operations, the bridge was constructed as two main cantilevers and three suspended spans, the three suspended spans being erected temporarily at a higher level. Stressing was then effected, using the anchorage against anchor blocks located at each end of the two cantilevers and the three suspended spans. The three suspended spans were then lowered onto the seating of the cantilevers and joined structurally by continuity cables passing through the adjacent anchor blocks. This operation is illustrated in the accompanying diagrams.

BRIDGE STATISTICS

Length.—1,100 feet in five spans. Centre span 320 feet with flanking spans each side of 230 feet and 160 feet.

Clearance.—Under central span 26 feet above normal water level for a width of 230 feet.

Road clearance under land spans a minimum of 15 feet.

Width of Bridge Deck.—Vehicular way, 70 feet.

Footways, 8 feet, separated from the roadway by a safety fence set back two feet from the roadway kerb.

Gradient of Bridge Deck.—The bridge deck profile is part of a vertical curve joining tangent lines of a grade 1 : 25 on the approach embankment.

Balustrading and Safety Fences.—In panels of anodised aluminium.

Lighting.—Aluminium standards set in the line of the safety fence at 80 feet centres carrying lanterns mounting three 80 watt fluorescent lights.

Services.—Five 30-inch diameter water mains and two 15-inch gas mains slung underneath the deck.

Lighting, high tension and P.M.G. cables under the footway slabs.

Approximate Quantities—

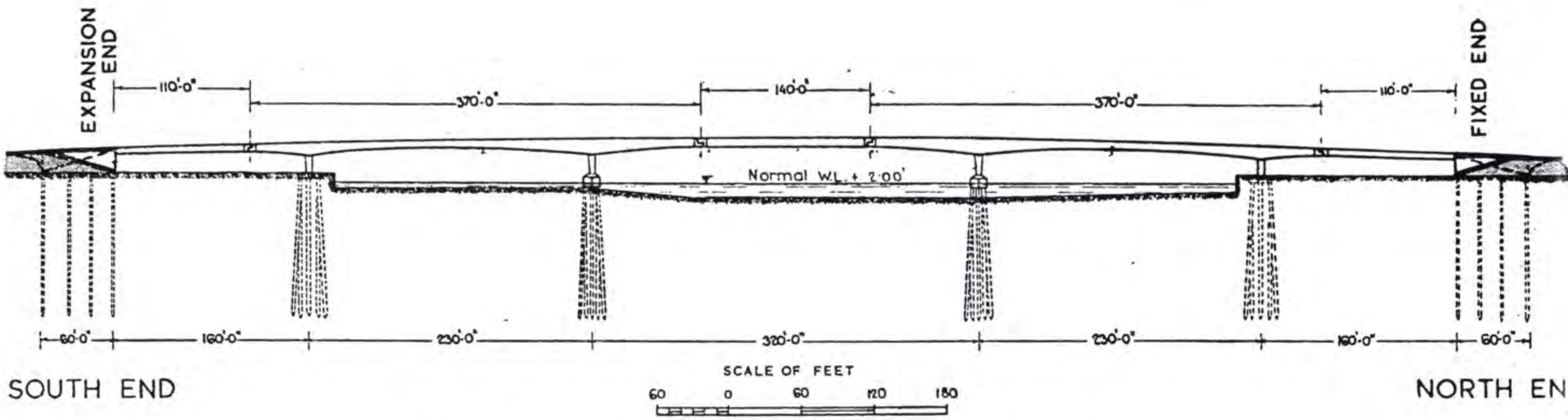
Gambia type foundation piles	20,960 lineal feet
Portland cement concrete	12,600 cubic yards
Mild steel reinforcement	2,000 tons
High tensile prestressing steel	325 tons
Roadway surfacing	8,600 square yards

PHOTOGRAPHS

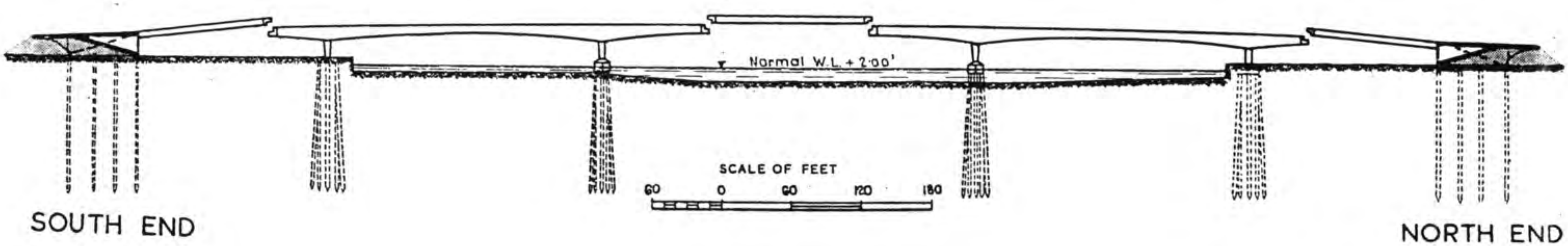
The photographs in the album show different stages in the construction.

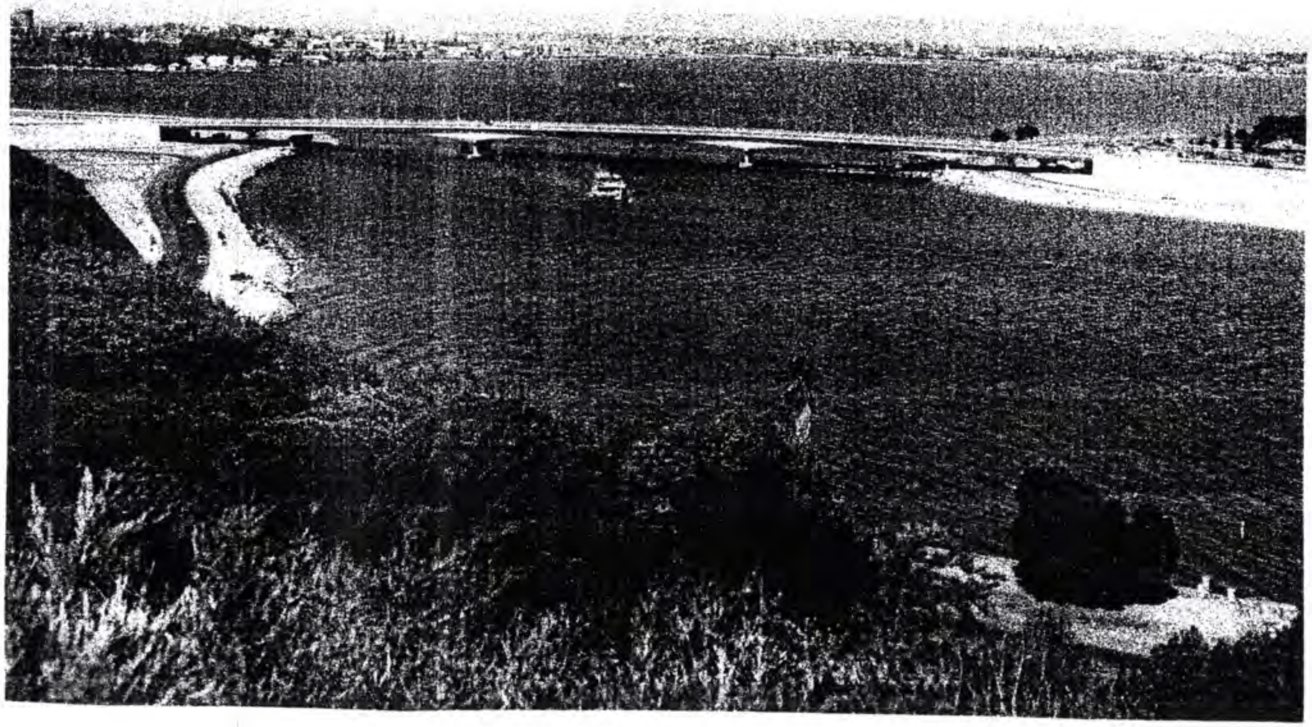
Whilst many of the stages were concurrent, for the purpose of grouping the following sequence has been adopted :—

A. Site conditions before commencing and after completion.
B. Temporary staging to provide an access track and support to receive the precast superstructure elements.
C. The foundations and pier system.
D. The abutment system.
E. The superstructure, including the lighting system, balustrading and road surfacing.
F. The opening ceremony on 13th November, 1959.
G. Plaques commemorating both the construction and the completion.

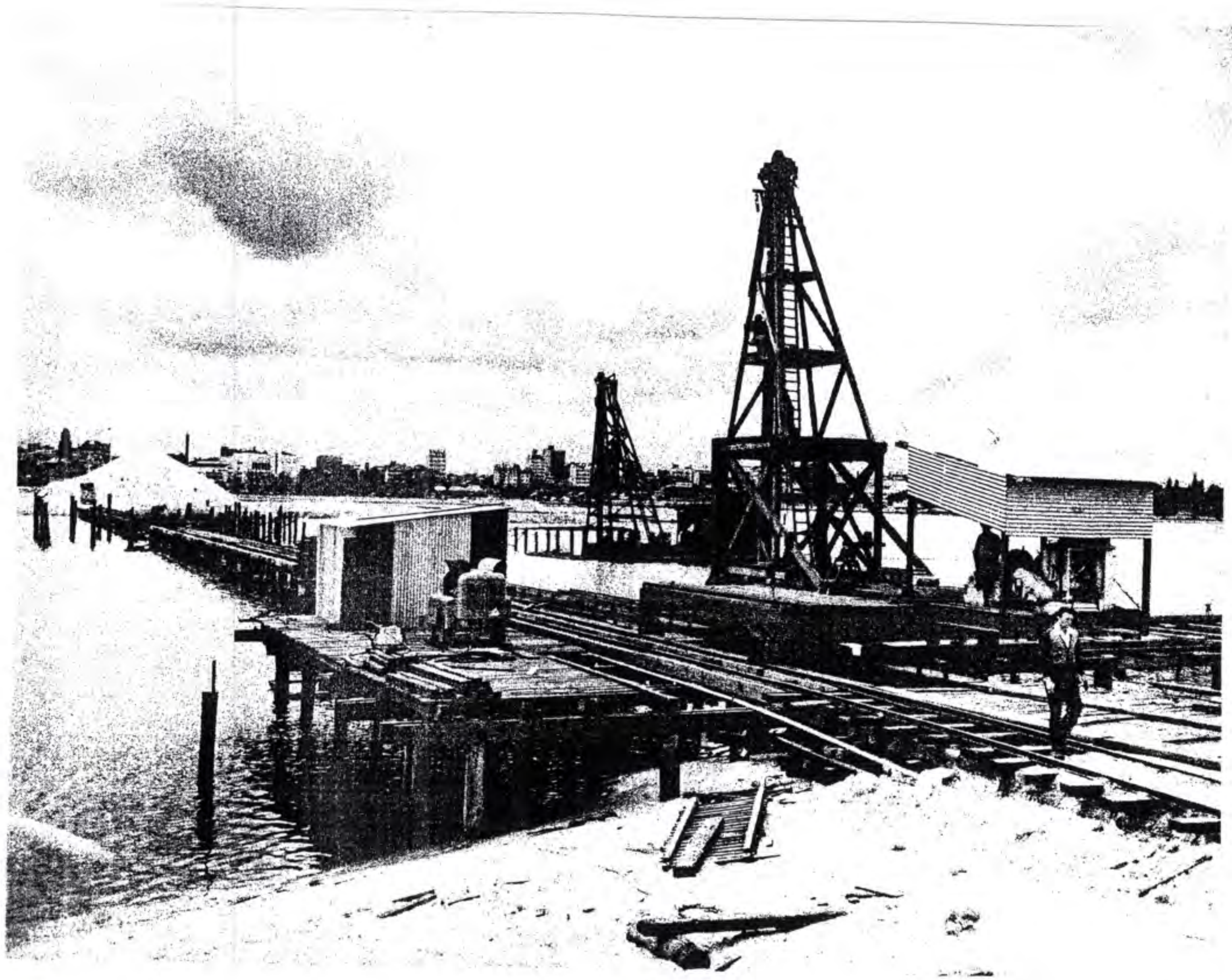


DIAG. I GENERAL FEATURES OF BRIDGE AS COMPLETED



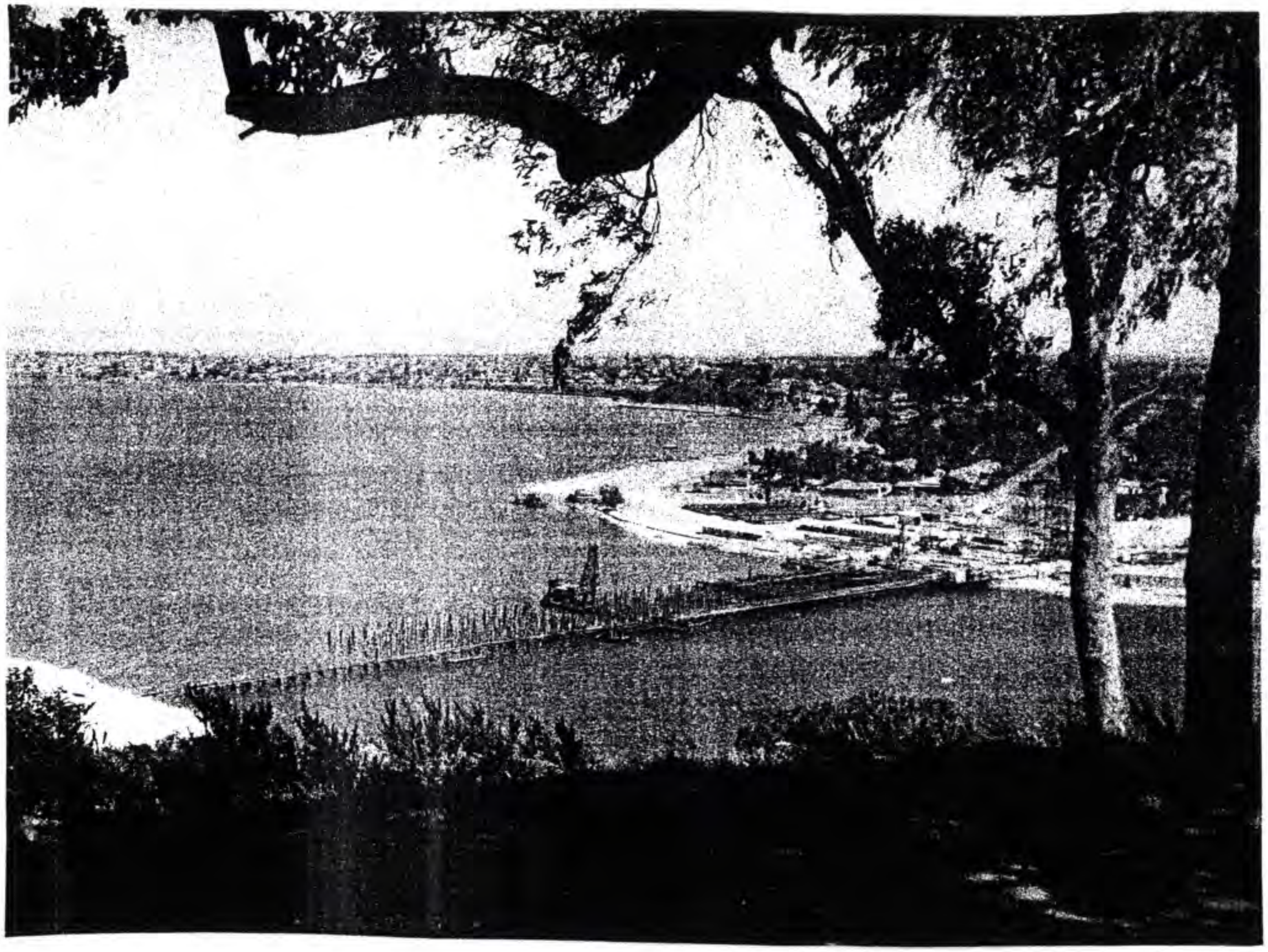


THE COMPLETED BRIDGE, 1959.



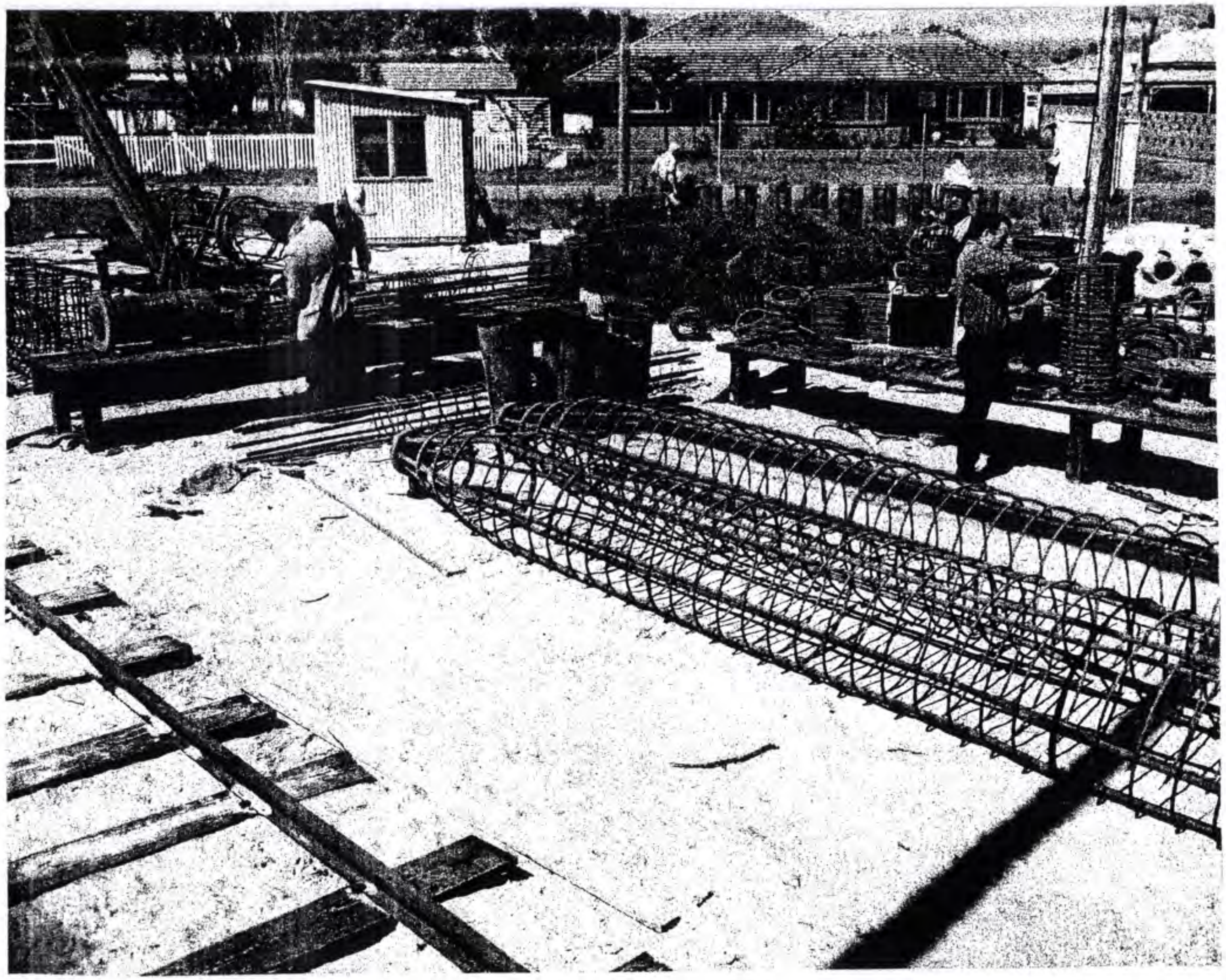
TIMBER PILLING FOR ACCESS TRACK AND TEMPORARY STAGING . TIMBER TRESTLING WILL BE MOUNTED ON THE PILLING AT A LATER DATE. IN THE BACKGROUND IS THE SURCHARGE NORTH EMBANKMENT.

RECLAMATION WORK IN PROGRESS FOR THE APPROACHES PRIOR TO THE COMMENCEMENT OF THE BRIDGE.

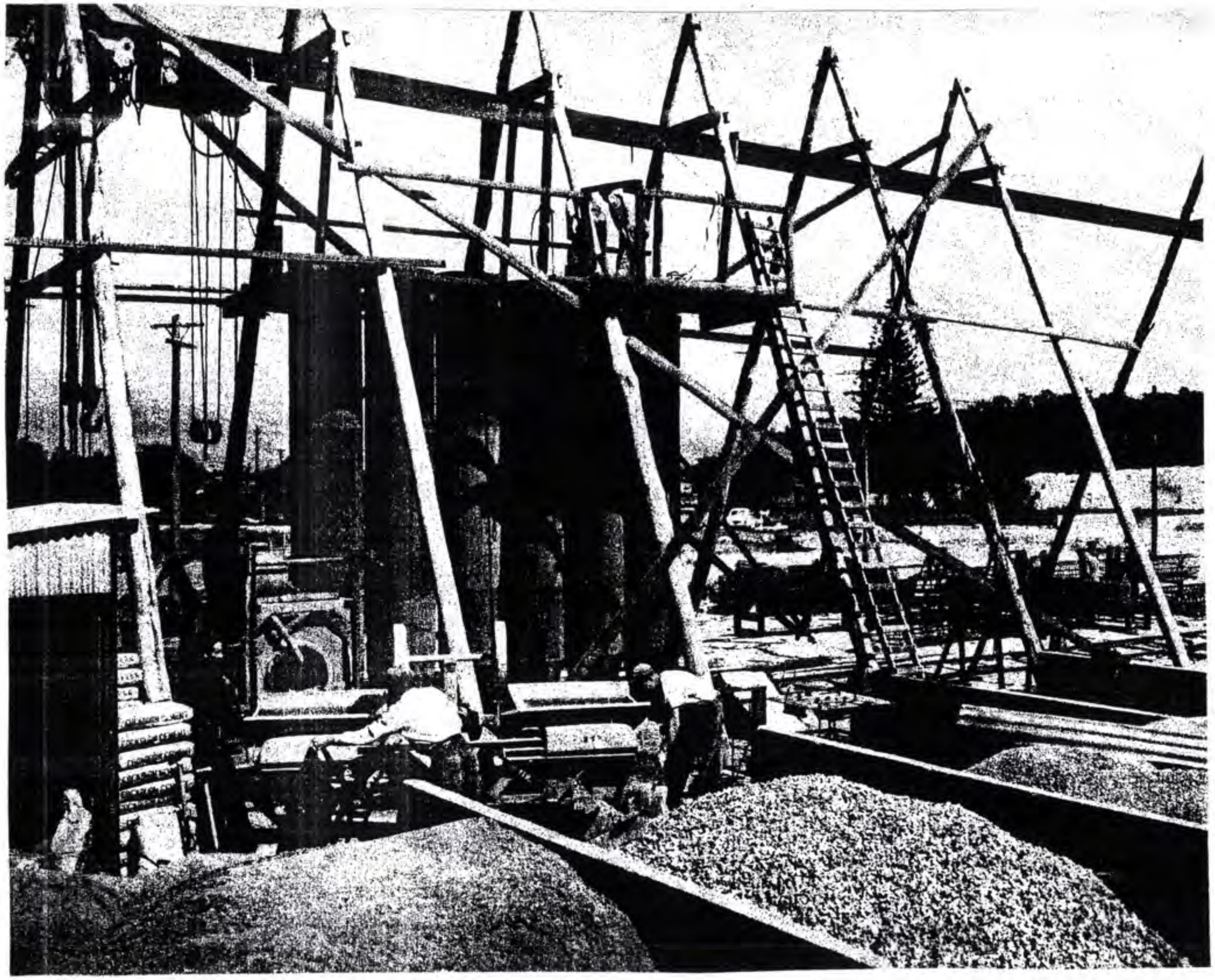


TEMPORARY PILLING BEING DRIVEN FROM A FLOATING PLANT. THE ACCESS TRACK IS COMPLETED. IN THE MIDDLE OF THE PHOTOGRAPH THE DROP SPAN FOR NAVIGATION IS SHOWN.

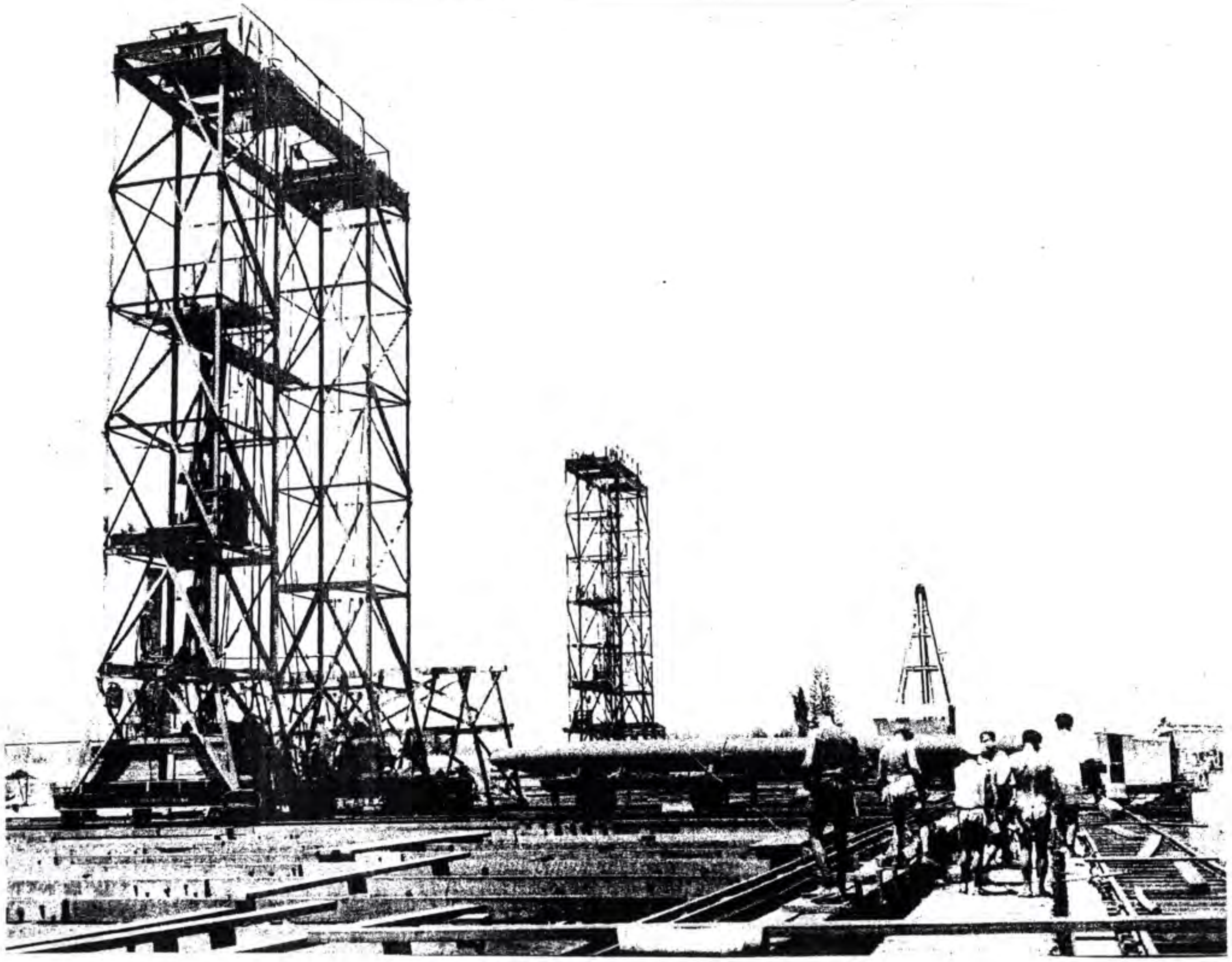
THE LOBNITZ ROCK BREAKER ADAPTED TO DRIVE THE INITIAL TEST PILE WITH THE 22TON NEEDLE. THIS TEST WAS MADE BEFORE THE CONTRACT WAS LET.



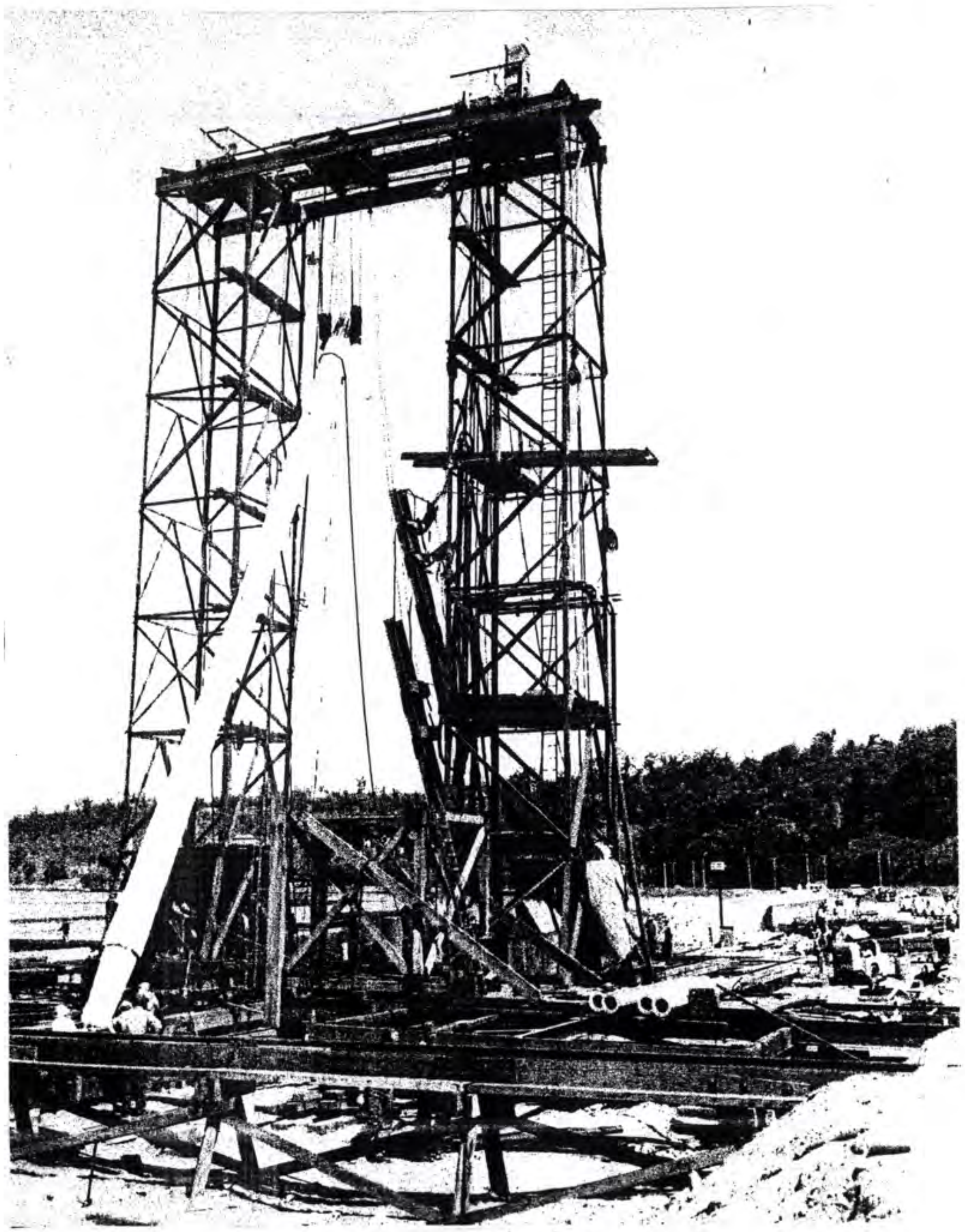
ASSEMBLY OF ANVIL AND REINFORCEMENT
CAGES FOR GAMBIA PILE TOES.



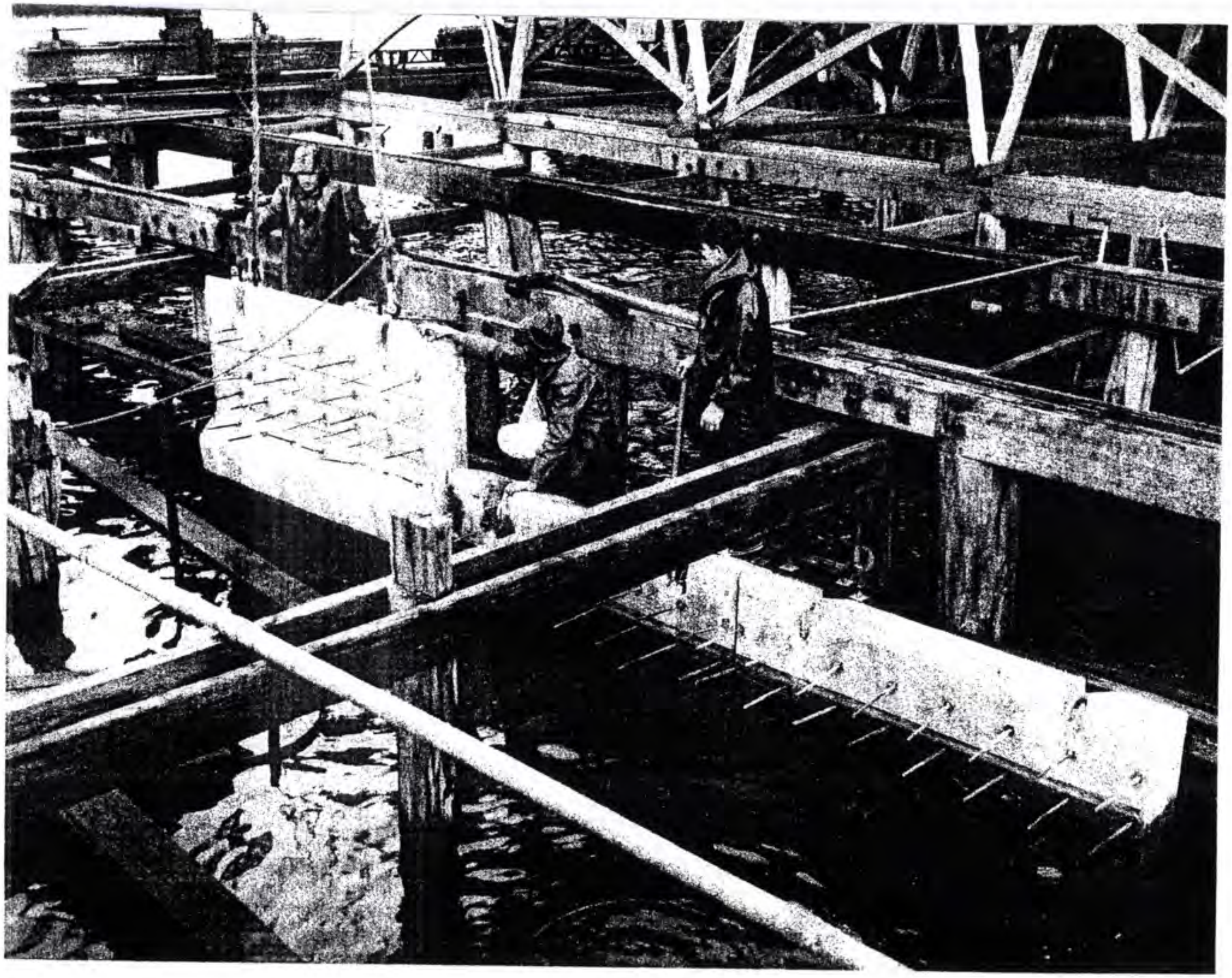
BATTERY OF GAMBIA PILE CASINGS READY TO RECEIVE CONCRETE SHOWING CONCRETE WEIGH BATCHER AND MIXER.



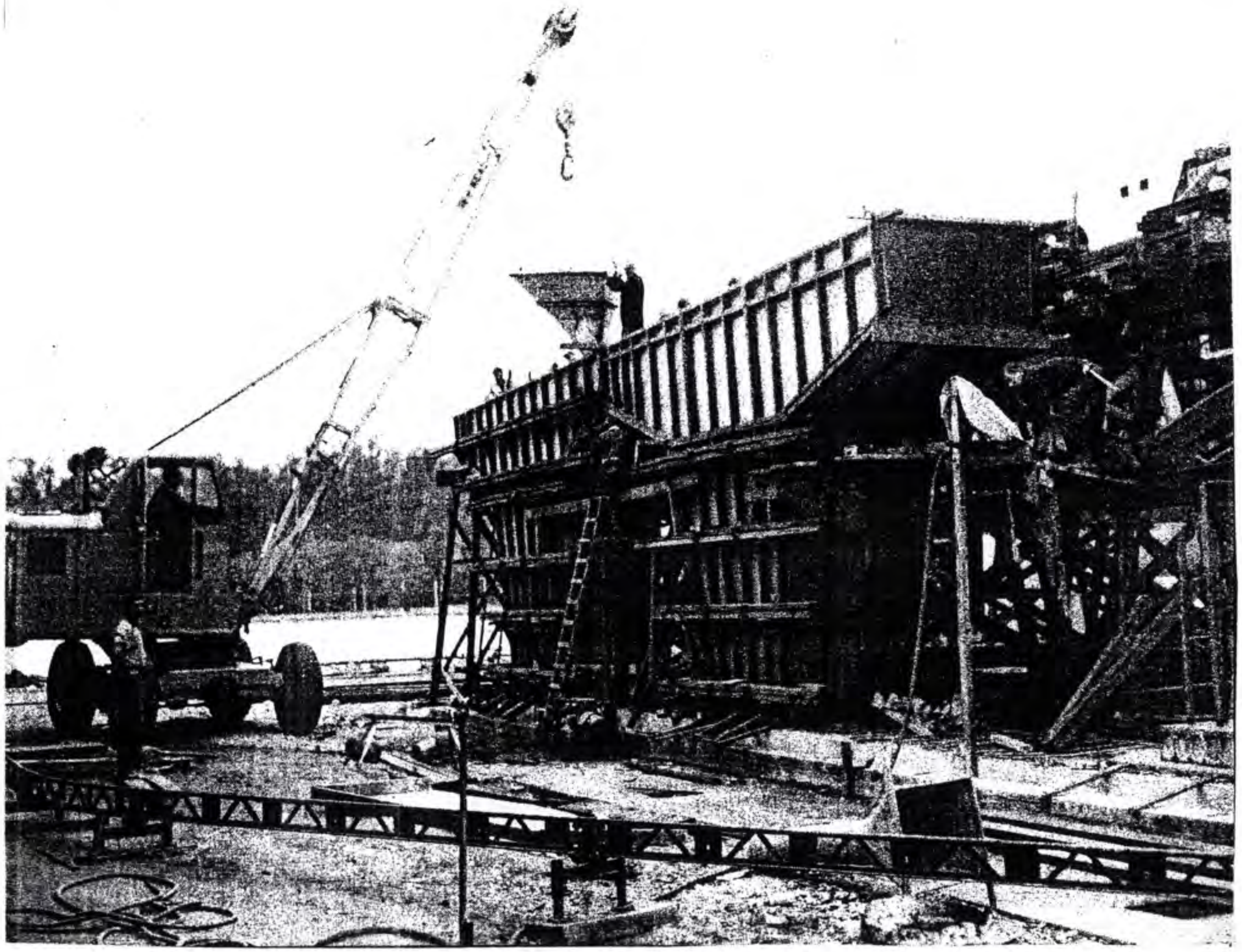
A 45-FOOT GAMBIA PILE BOTTOM SECTION BEING TRANSPORTED INTO POSITION FOR PITCHING. THE DRIVING RIG IS AT THE SOUTH PIER LOCATION.



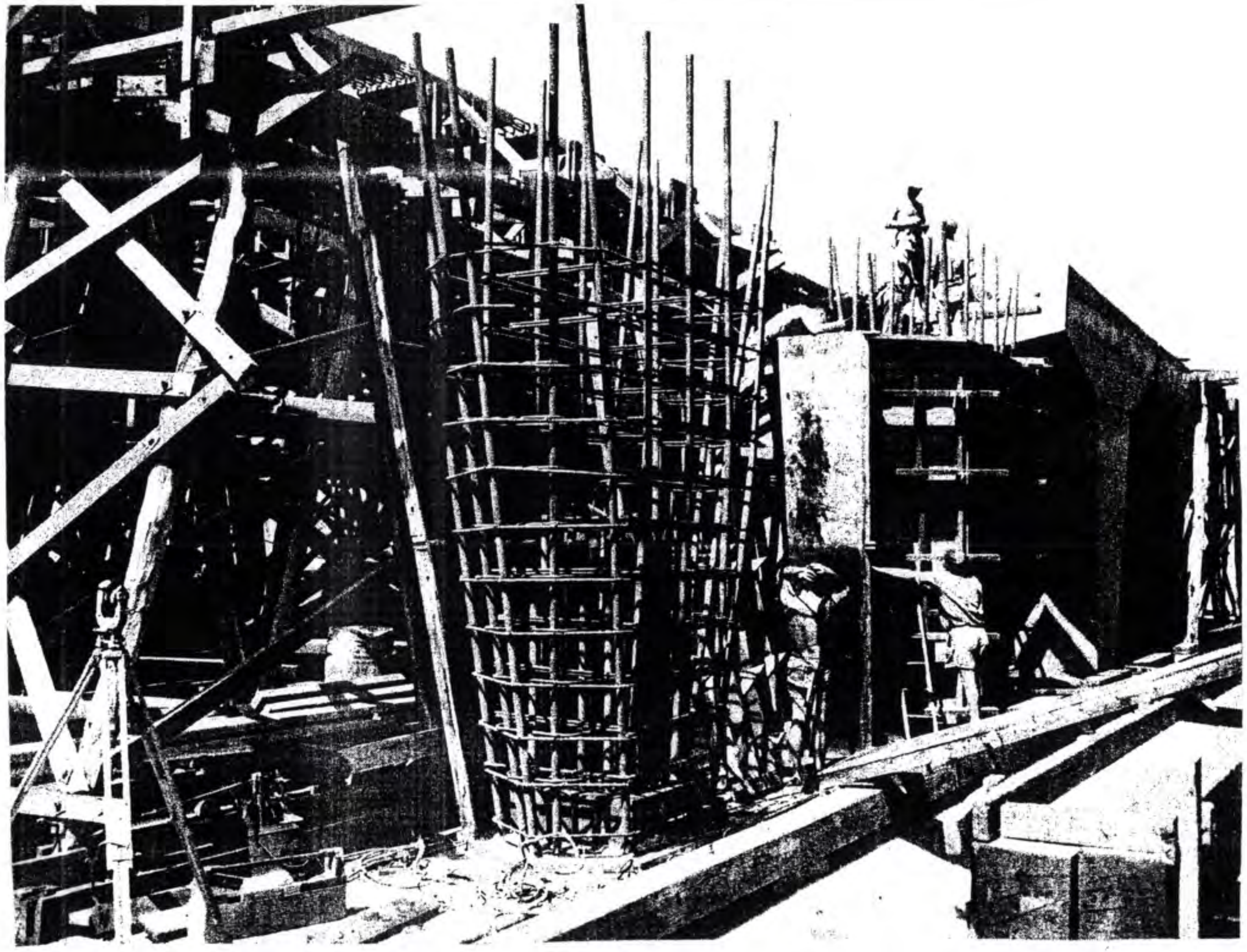
A PRECAST 65-FOOT PILE BEING LIFTED INTO THE FRAME AT THE NORTH SHORE PIER. THIS IS SUBSEQUENTLY FED DOWN THE MODIFIED GAMBIA PILE CASING AND CONCRETE IN AT THE BOTTOM TO JUNCTION WITH CONCRETE ALREADY POURED IN THE BOTTOM OF THE CASING.



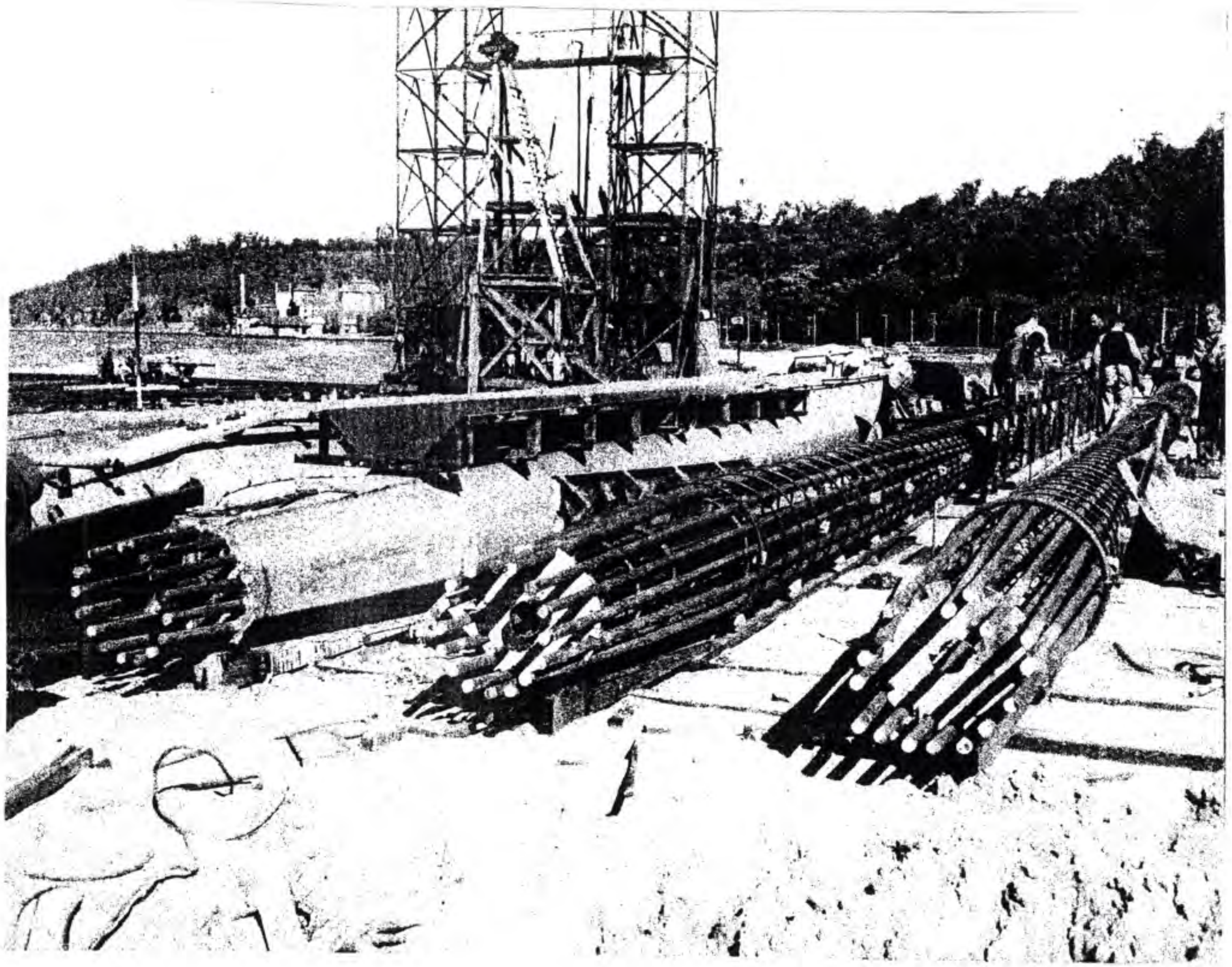
PIER SKIRTING SLABS BEING PLACED AS A SURROUND TO A RIVER PIER CAP. THE SLAB EXTEND BELOW WATER LEVEL TO CONCEAL THE PILE HEADS WHICH FINISH ABOVE WATER LEVEL.



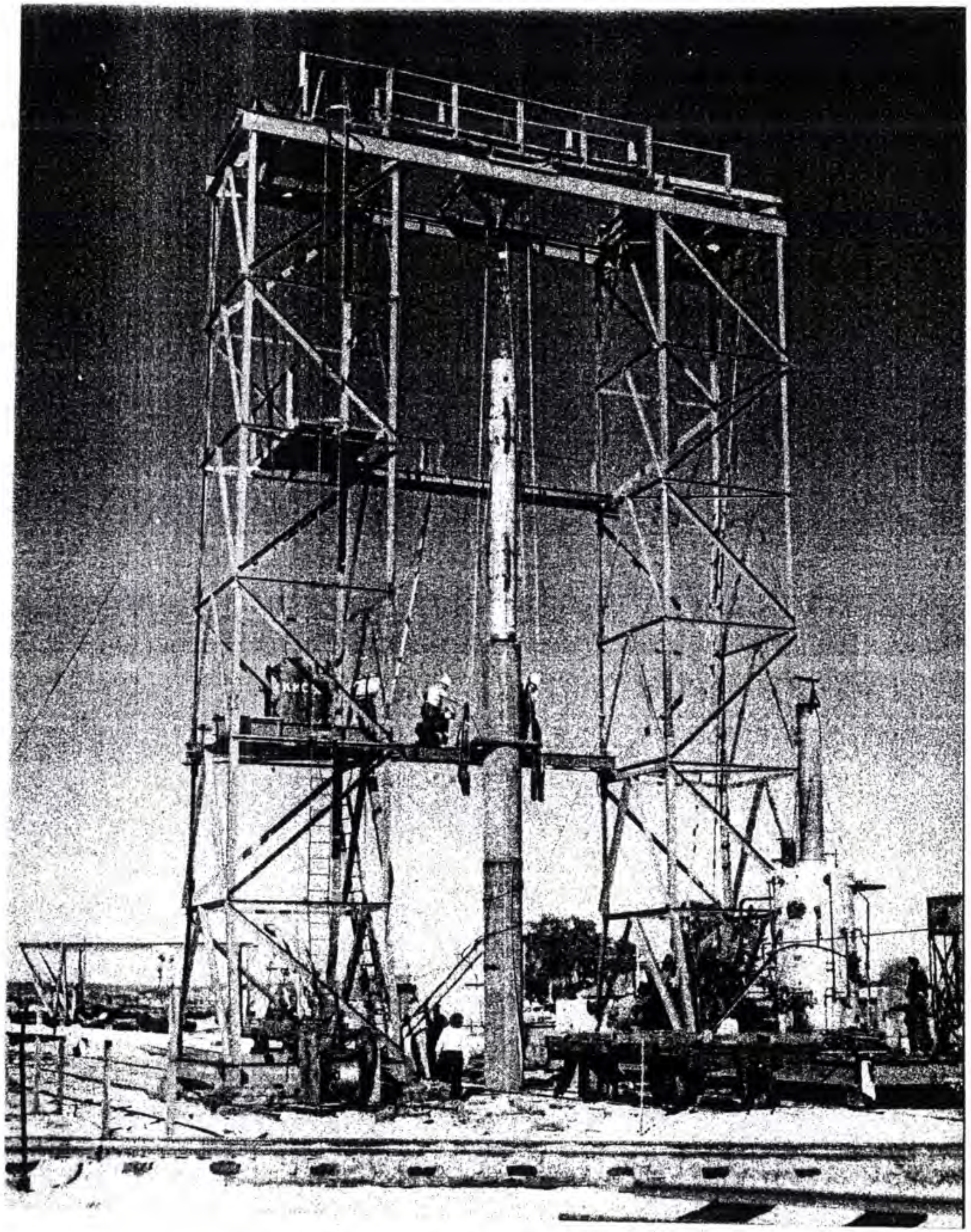
FORMWORK FOR CONSTRUCTION OF TWO PIER COLUMNS AT A SHORE PIER. THE LOWER BEARING OF A THIRD COLUMN IS SEEN AT THE RIGHT OF THE PHOTOGRAPH.



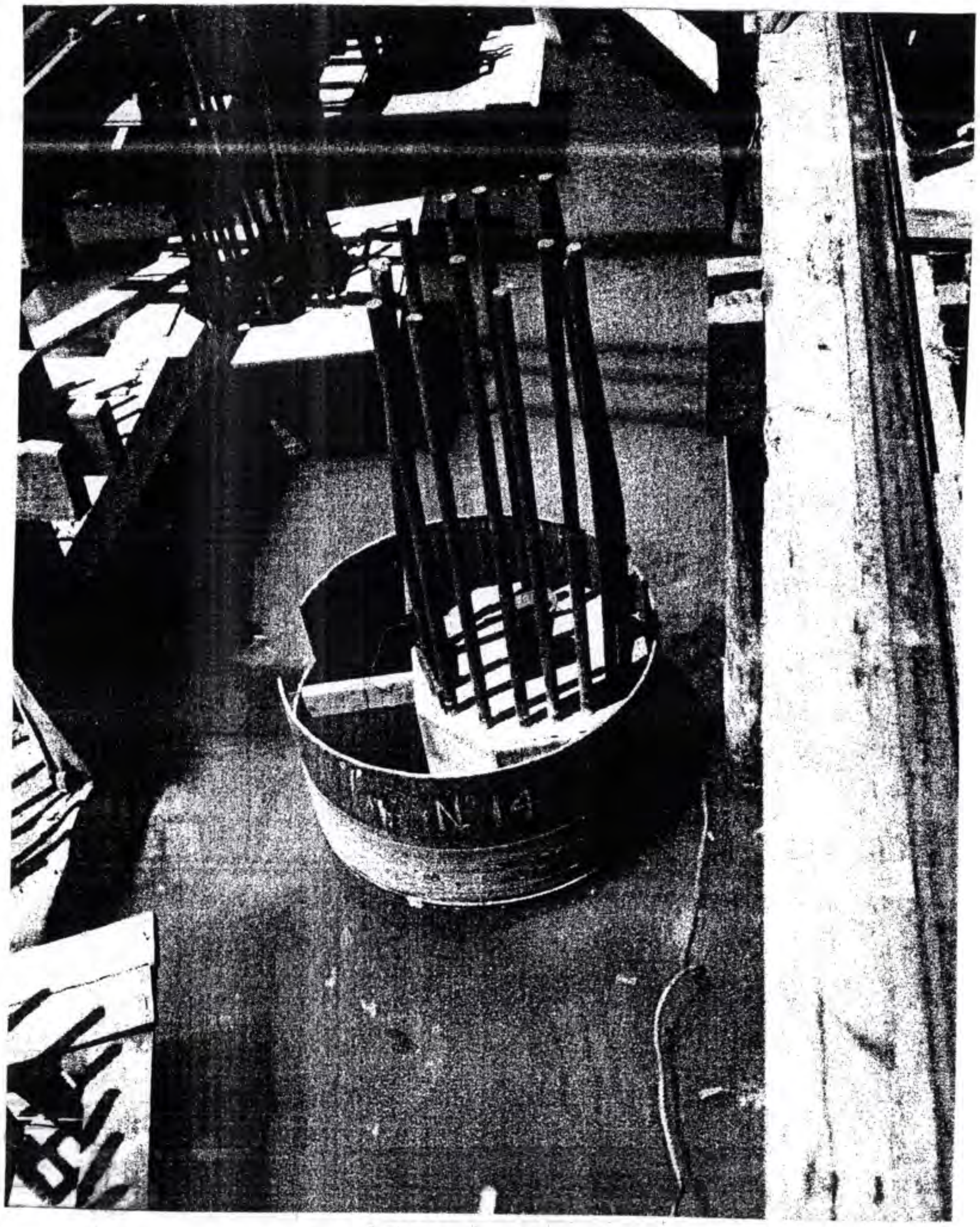
CONSTRUCTION OF PIER COLUMNS AT A RIVER PIER. THE NEAREST COLUMN REINFORCEMENT IS BEING SET UP. ONE COMPLETED COLUMN IS SEEN.



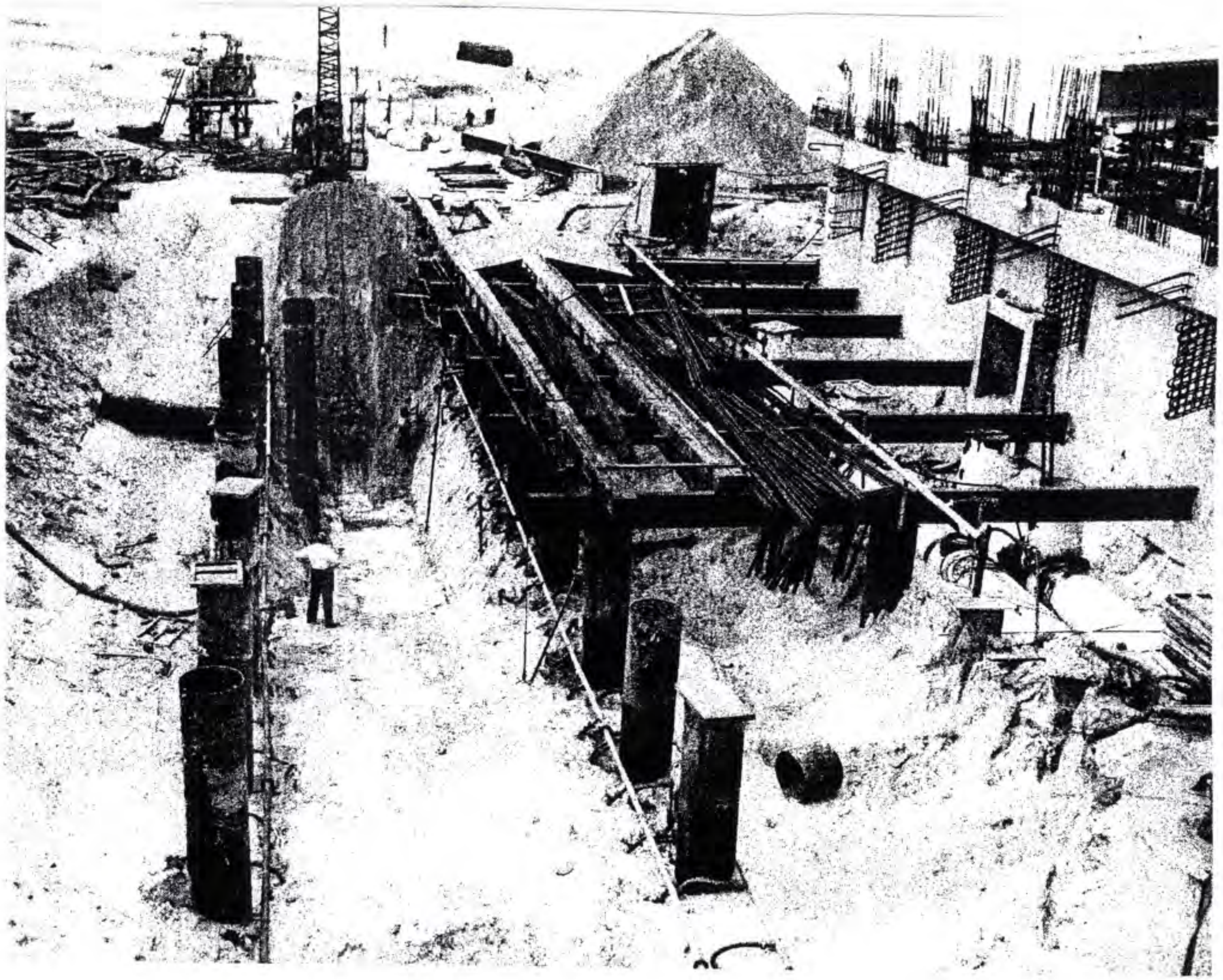
PRECAST CONCRETE PILES FOR SPECIAL TREATMENT AT THE NORTH SHORE PIER. THERE ARE TWO REINFORCEMENT CAGES IN THE RIGHT FORGROUND WITH ONE COMPLETED PILE AT THE LEFT.



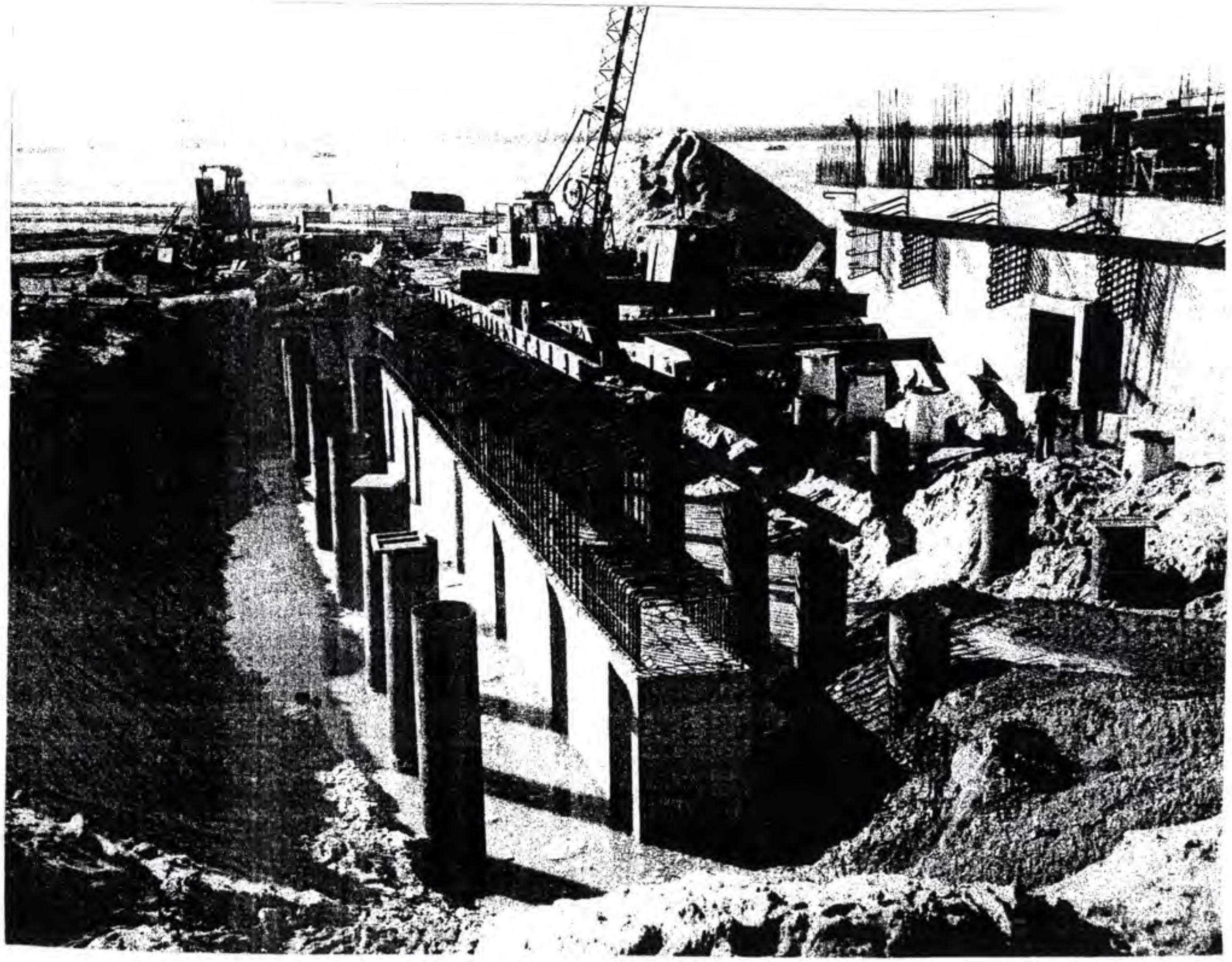
A PILE-DRIVING FRAME SHOWING THE 10-TON DRIVING HAMMER SUSPENDED BEFORE LOWERING INTO THE CASING. GATES ON THE TRANSVERSE MEMBERS BETWEEN THE MAIN LEGS GUIDE THE PILES DURING DRIVING.



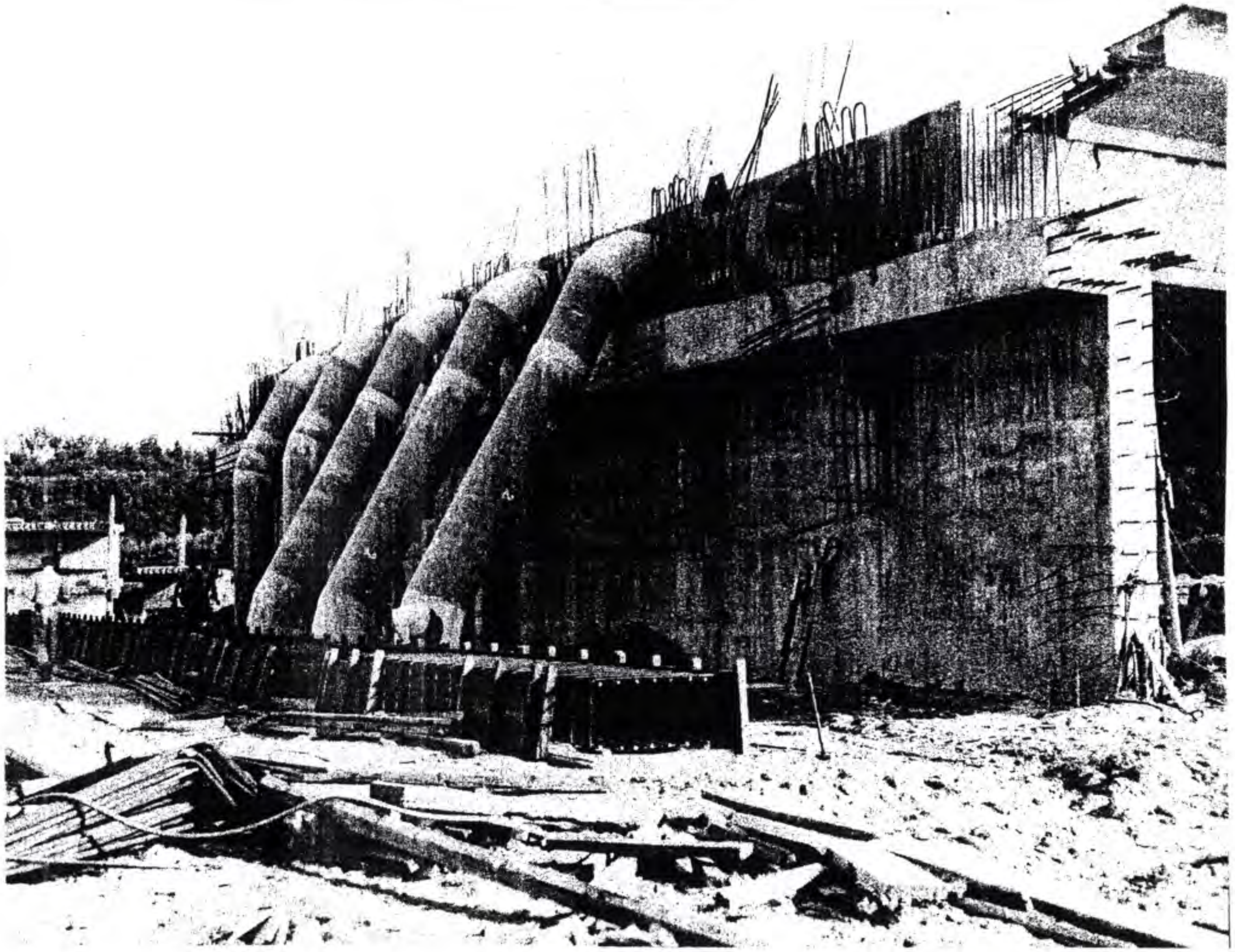
THE HEAD OF AN OFFSET PRECAST PILE IN THE SPECIAL GAMBIA CASING AT THE NORTH SHORE PIER. SMALL ANTICIPATED EARTH MOVEMENTS COULD DEFORM THE CASING WITHOUT IMPOSING A THRUST ON THE PILE.



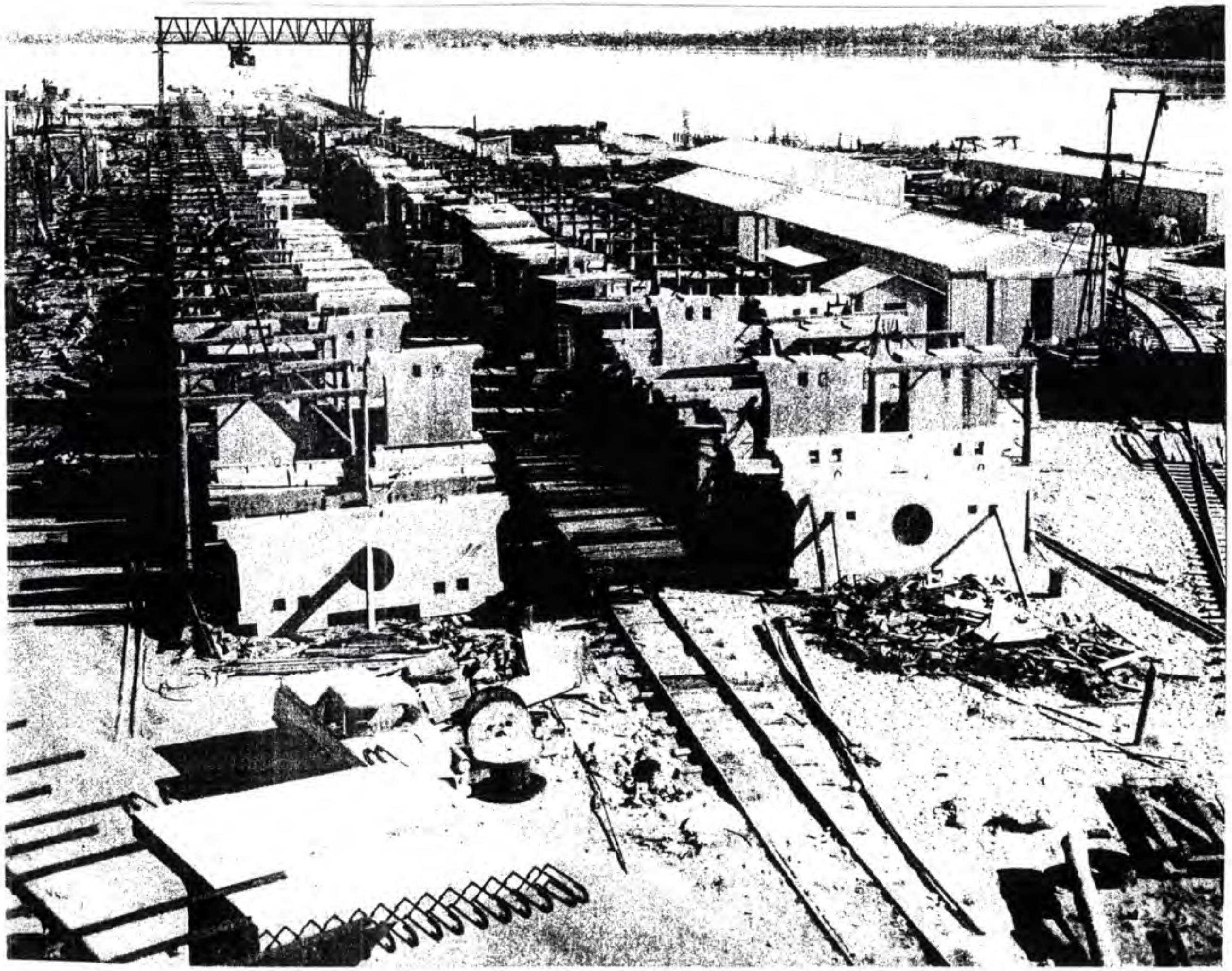
EXCAVATION AT THE NORTH ABUTMENT. THE MAIN ABUTMENT WALL IS AT THE RIGHT. SHOWN ALSO ARE LINES OF GAMBIA PILES TO TAKE THE CAPS WHICH WILL SUPPORT THE SLOPING BEAMS LEADING DOWN FROM THE ABUTMENT WALL.



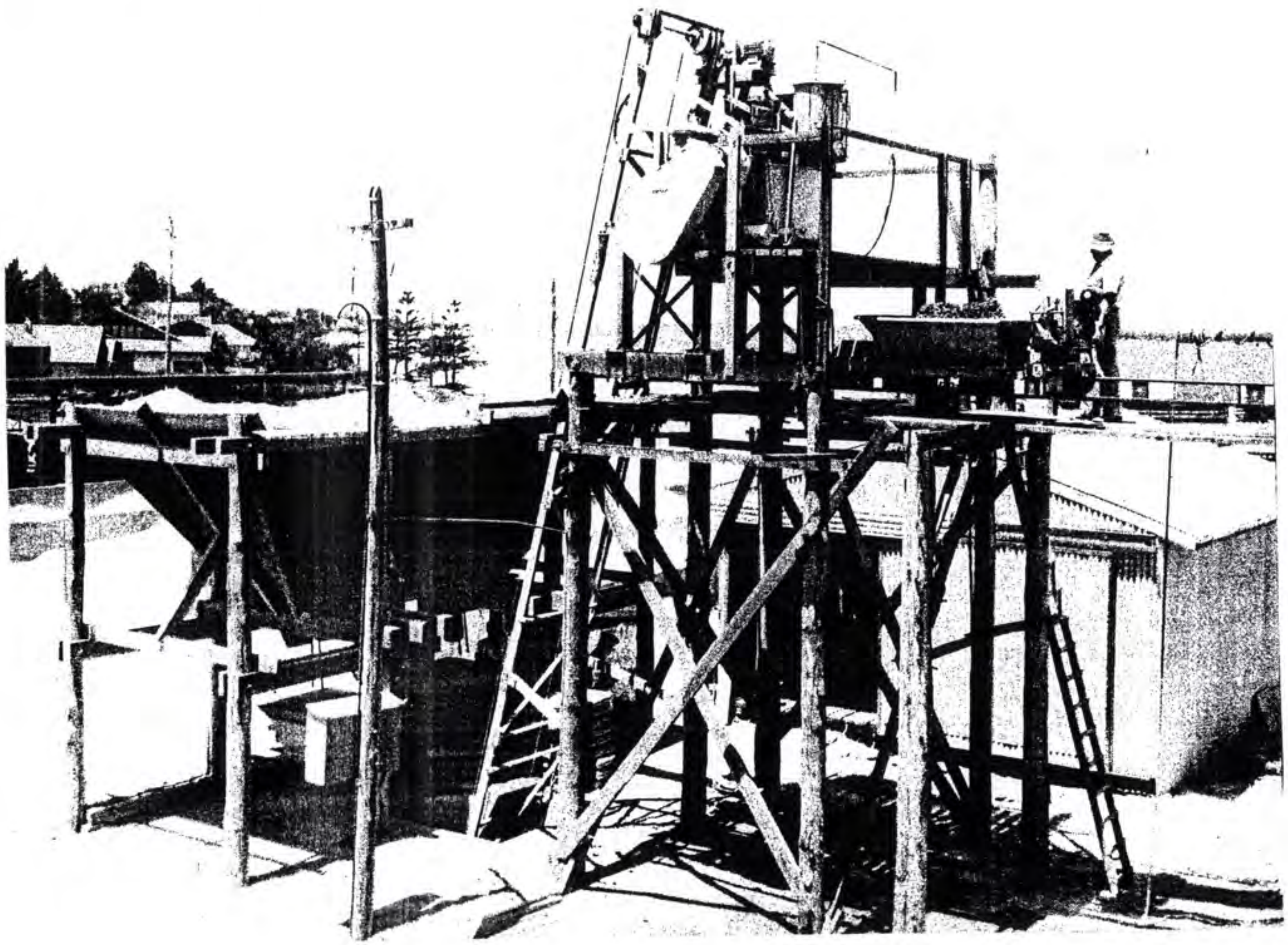
A FURTHER STAGE IN CONSTRUCTION AT THE NORTH ABUTMENT. THE BUTTRESS WALL HAS BEEN CAST.



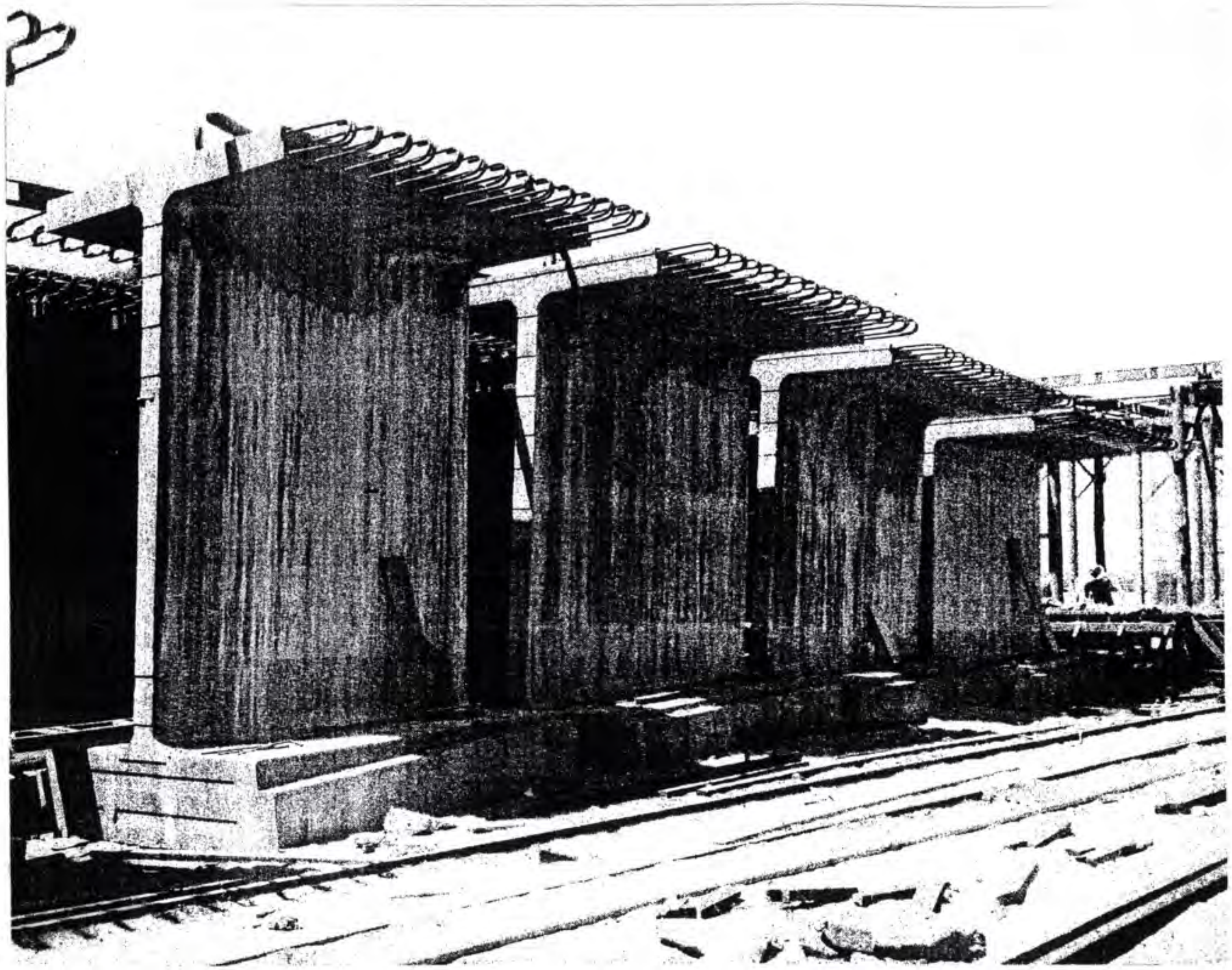
AN EARLY STAGE IN CONSTRUCTION AT THE SOUTH ABUTMENT SHOWING THE FIVE 30-INCH DIAMETER WATER MAINS.



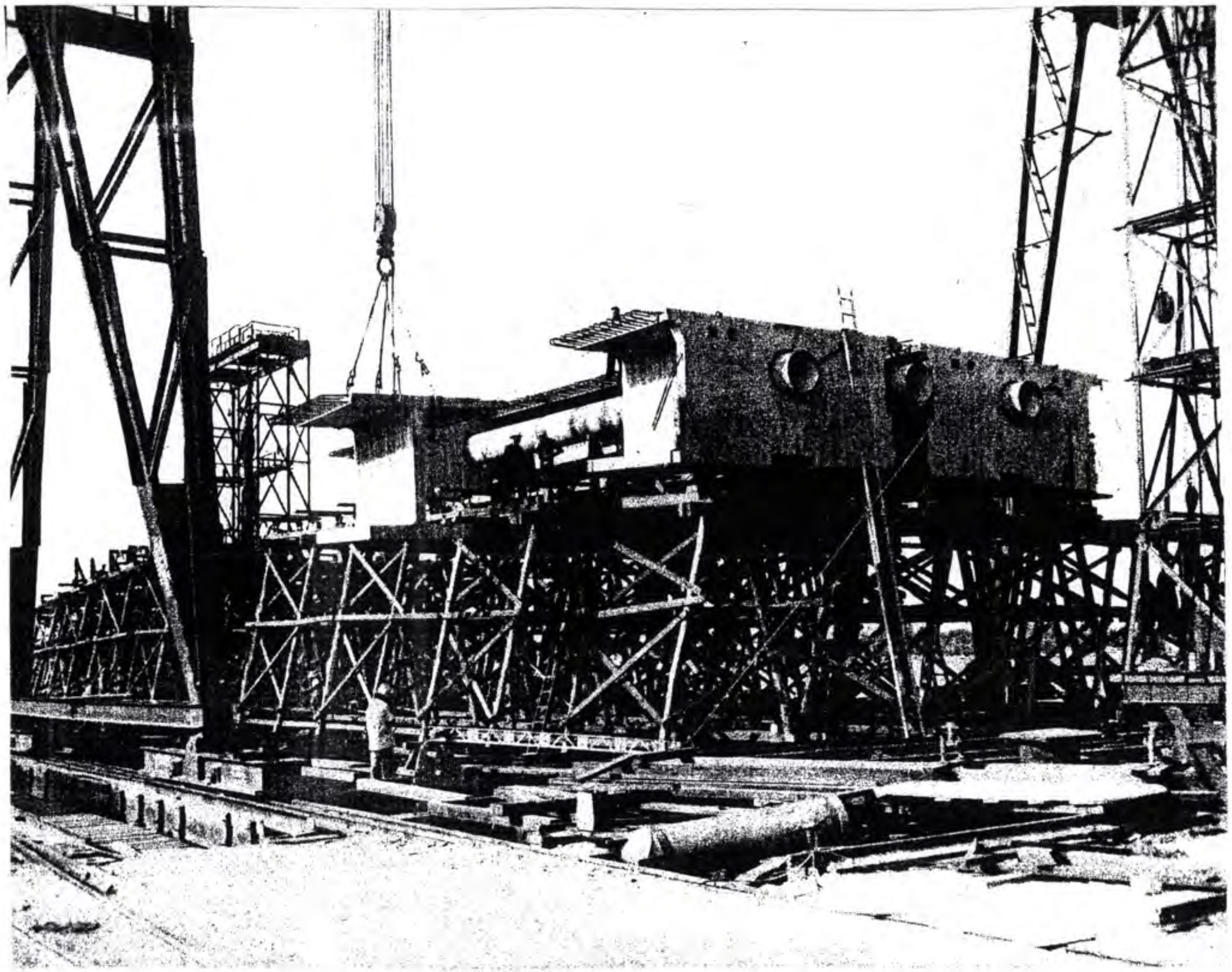
A GENERAL VIEW OF THE YARD ON THE SOUTH SIDE IN WHICH THE BRIDGE ELEMENTS WERE PRECAST.



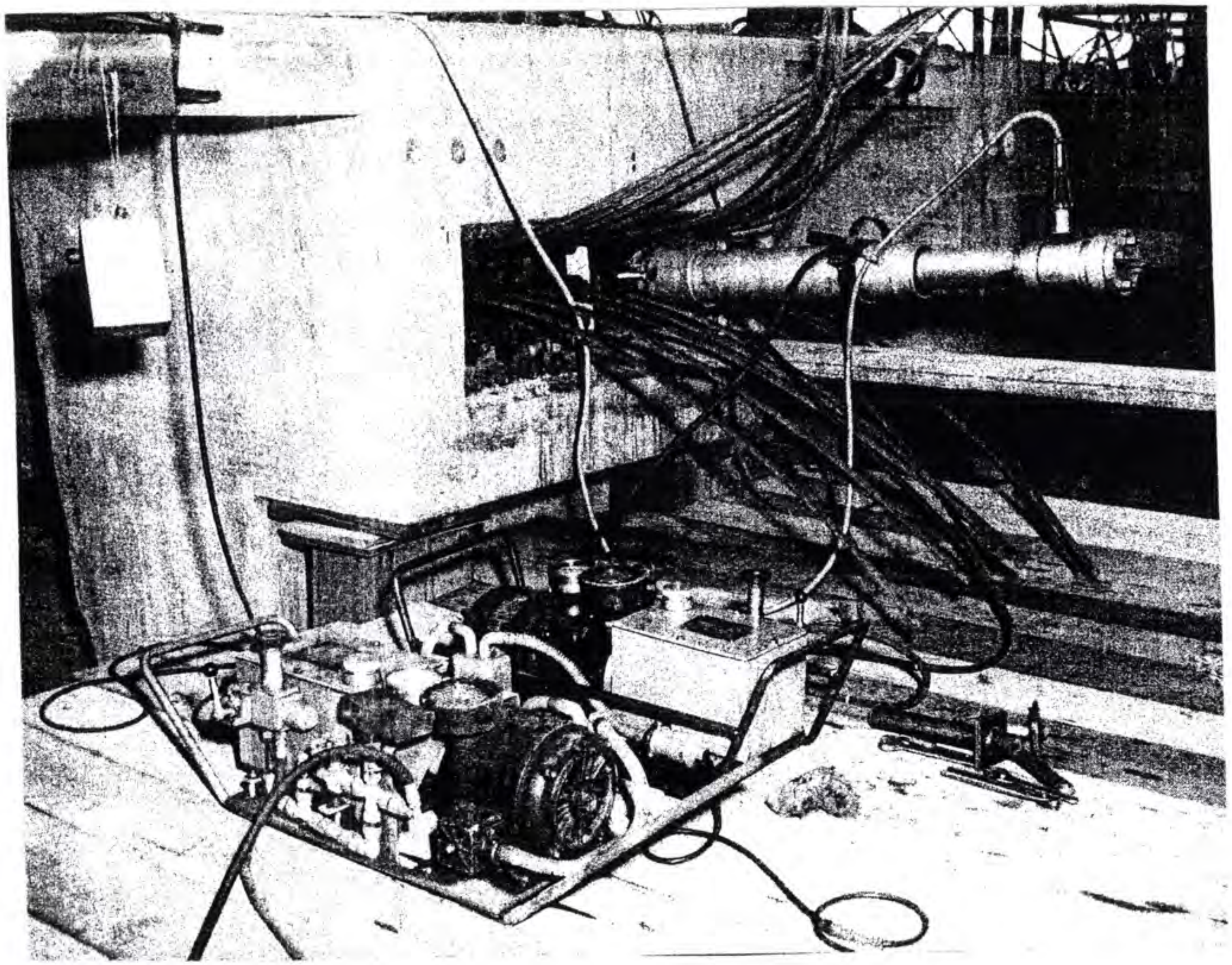
CUMFLOW PAN CONCRETE MIXER IN THE CASTING YARD. THE MIXER IS LOCATED OVER THE MONORAIL TRACK. THE WEIGH BATCHER IS LOCATED BELOW THE TIMBER HOPPER WHICH IS DIVIDED INTO FOUR COMPARTMENTS.



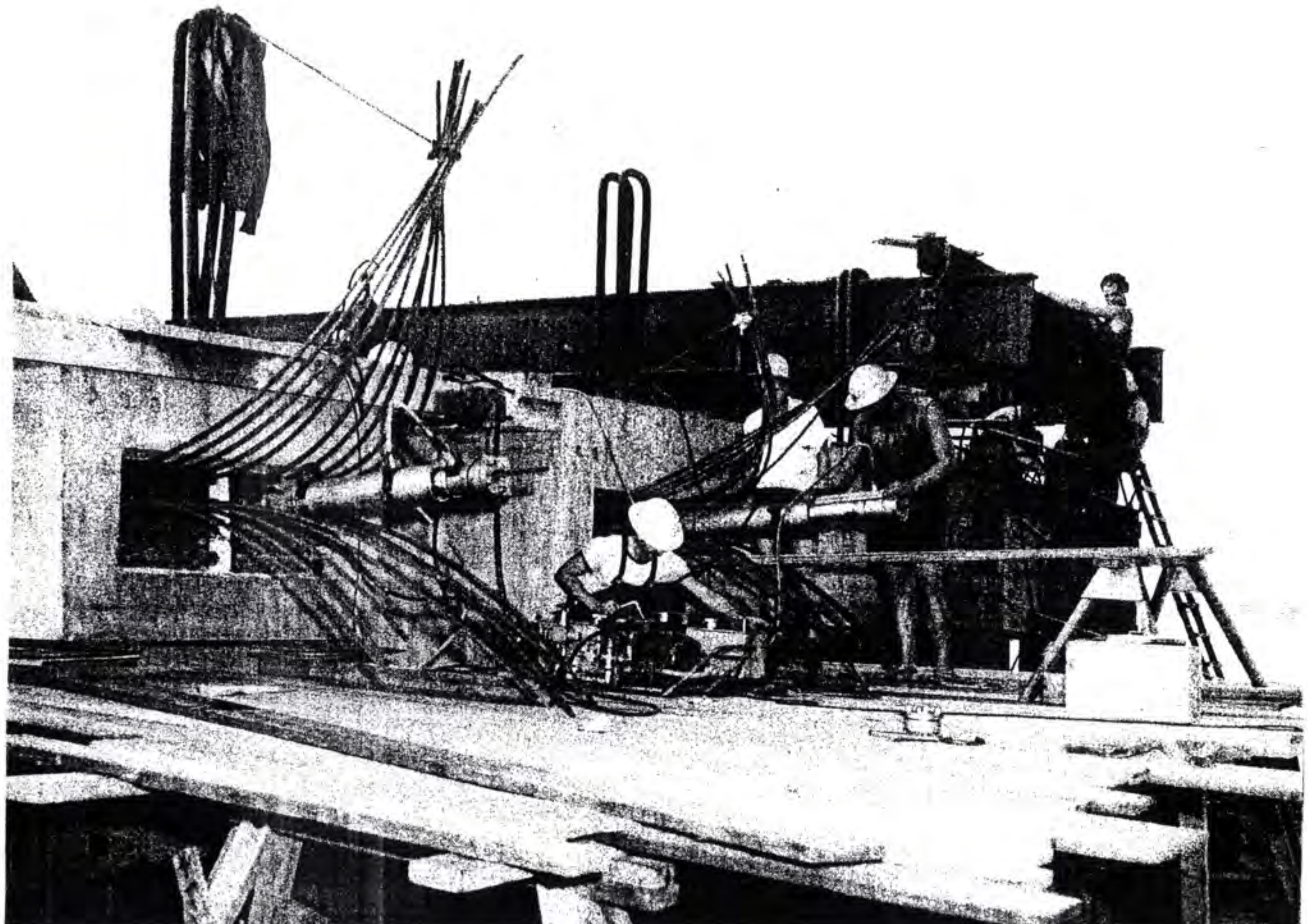
PRECAST BEAM ELEMENTS ON STORAGE BEDS.
THE UNITS ARE SOME OF THE LARGEST ON
THE JOB. THE UNITS WERE CAST IN TWO LIFTS.



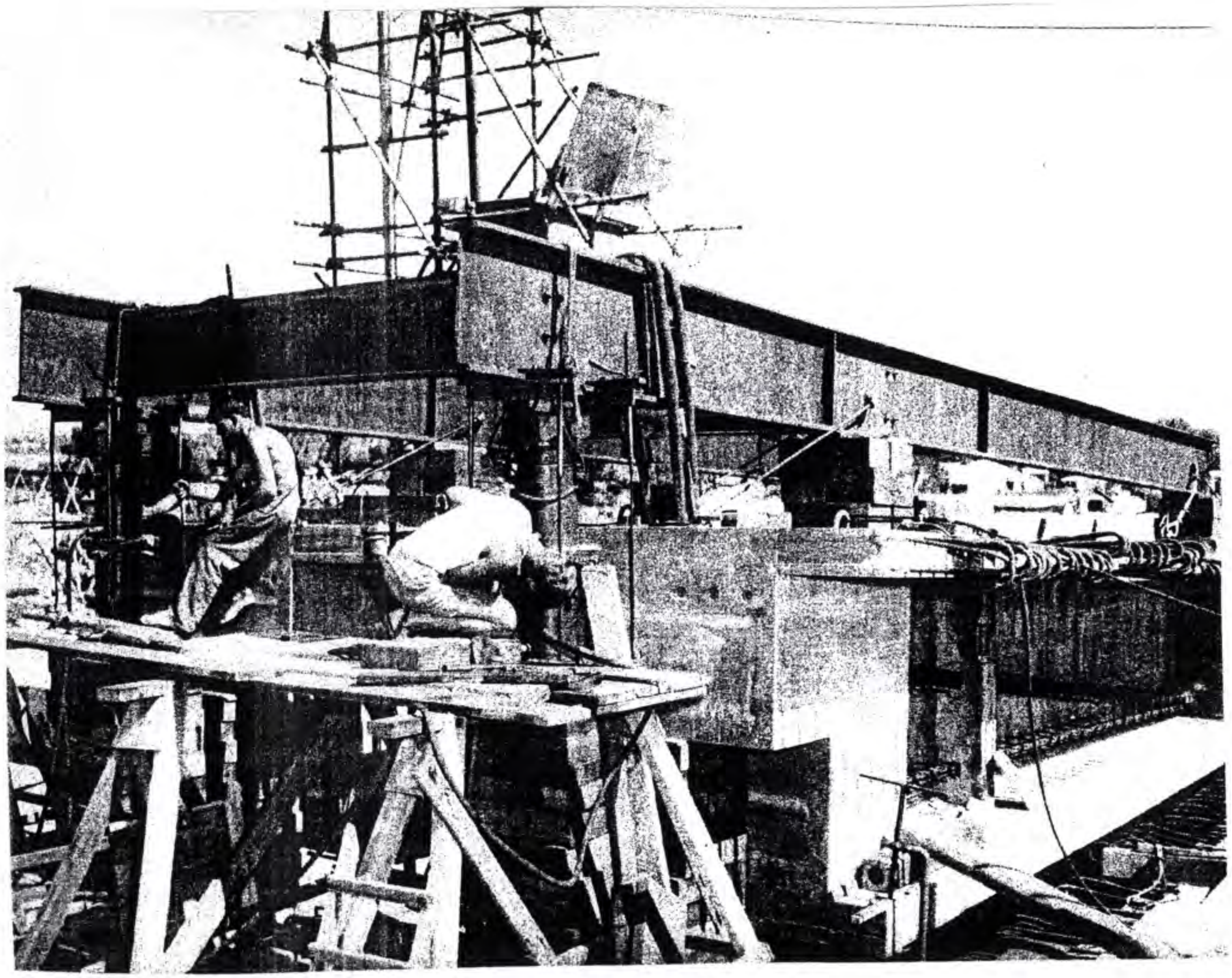
ERECTION OF BEAM ELEMENTS ON
TEMPORARY TRESTLES. AN ELEMENT IS BEING
PLACED BY THE OVERHEAD GANTRY.



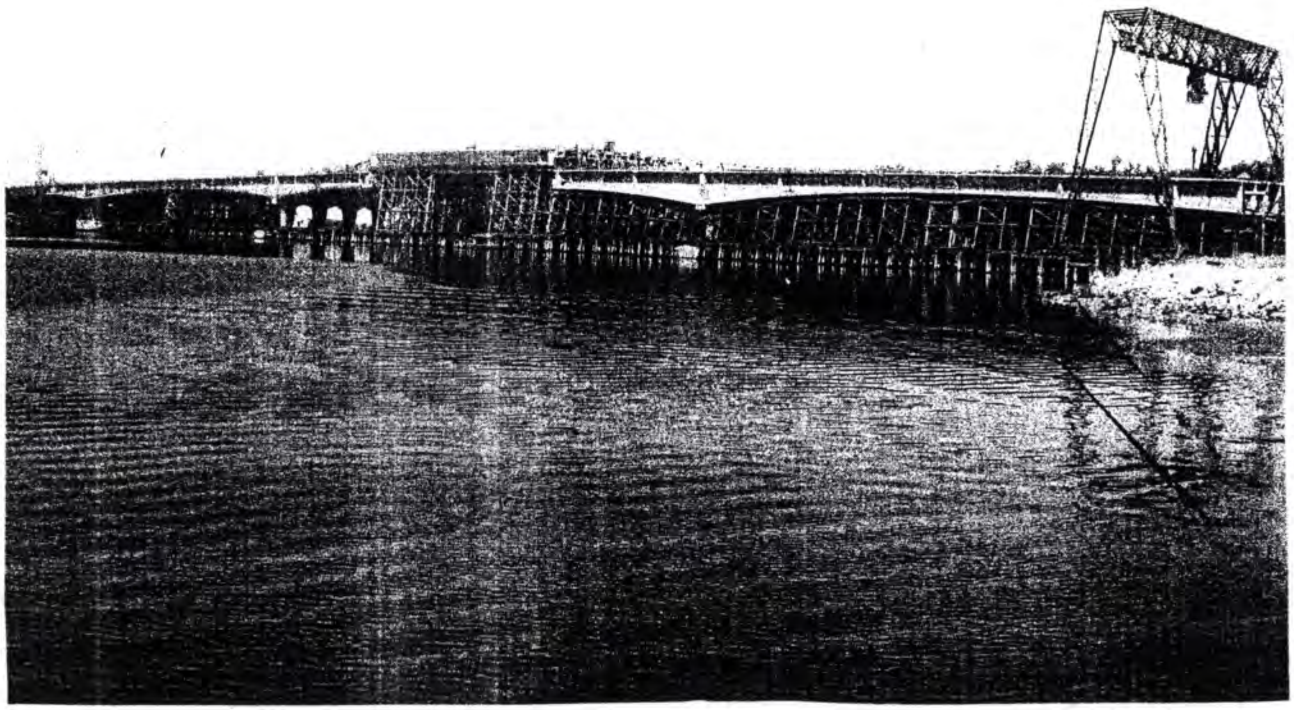
STRESSING JACK AND END ANCHORAGE FOR THE GIFFORD UDALL SYSTEM. THE PHOTO SHOWS THE ELECTRICALLY DRIVEN HYDRAULIC PUMP IN THE FOREGROUND, THE HYDRAULIC JACK, AND AT ITS END THE LOAD CELL LEADING TO THE CONTROL PANEL.



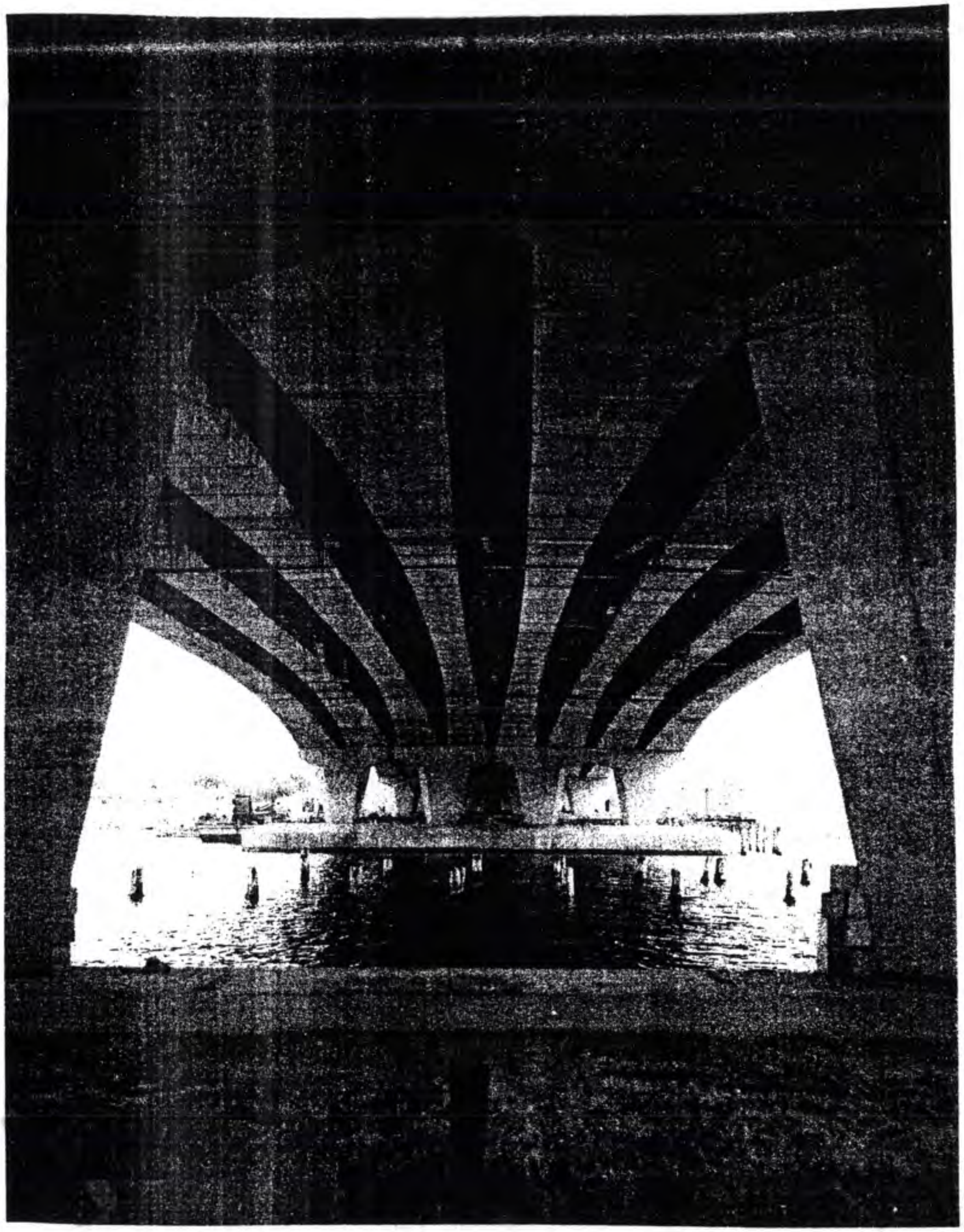
A GENERAL VIEW OF STRAND STRESSING BY THE GIFFORD UDALL METHOD. THE TWO BEAMS IN THE BACKGROUND, ALREADY STRESSED, ARE BEING PREPARED FOR LOWERING.



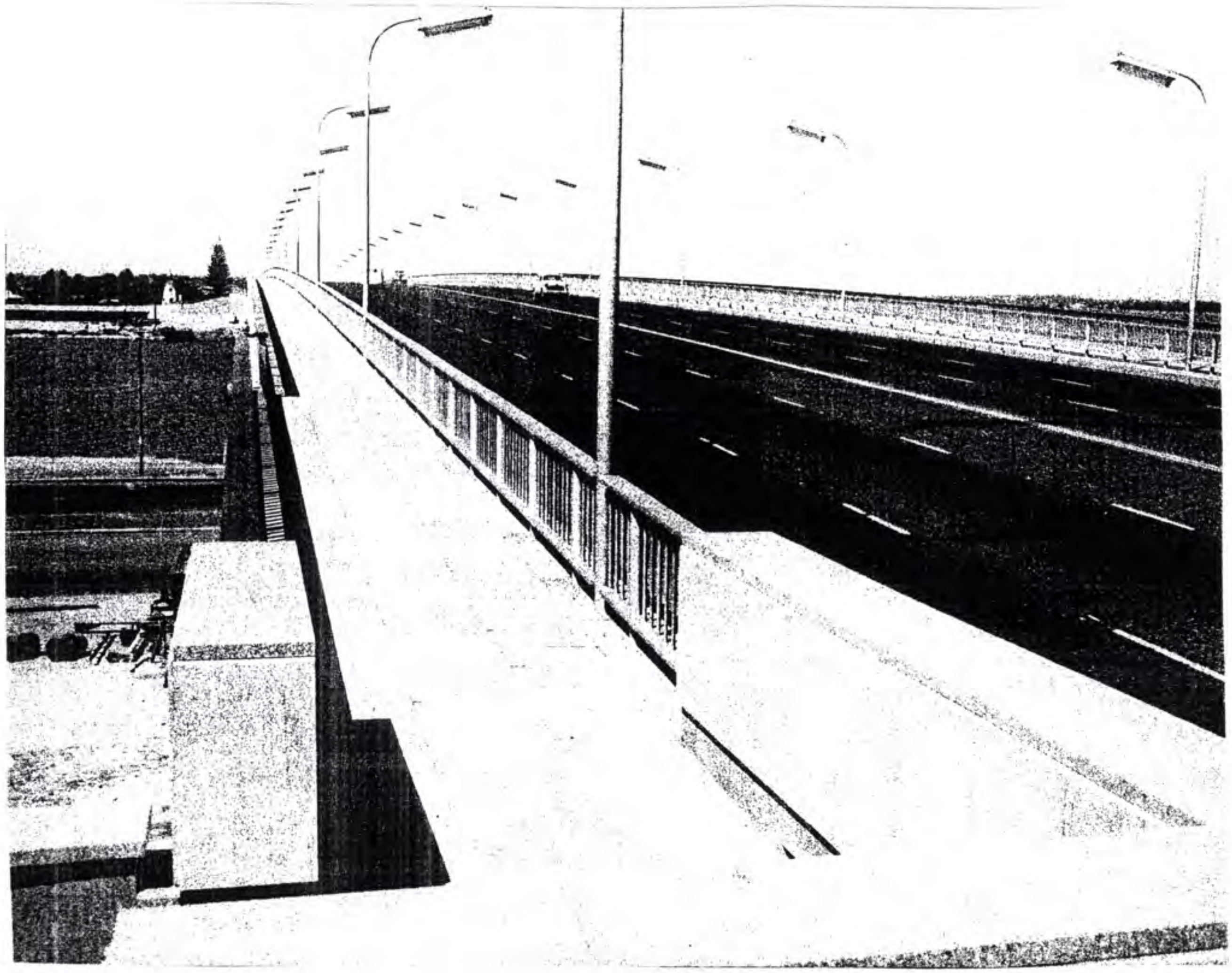
JACKING DOWN A SUSPENDED SPAN. JACKING WAS DONE SIMULTANEOUSLY ON TWO LINES OF BEAMS. FOUR 100-TON JACKS WERE USED.



A GENERAL VIEW FROM UP RIVER SHOWING THE CENTRAL SUSPENDED SPAN AT A HIGH LEVEL PREPARTORY TO STRESSING AND LOWERING.

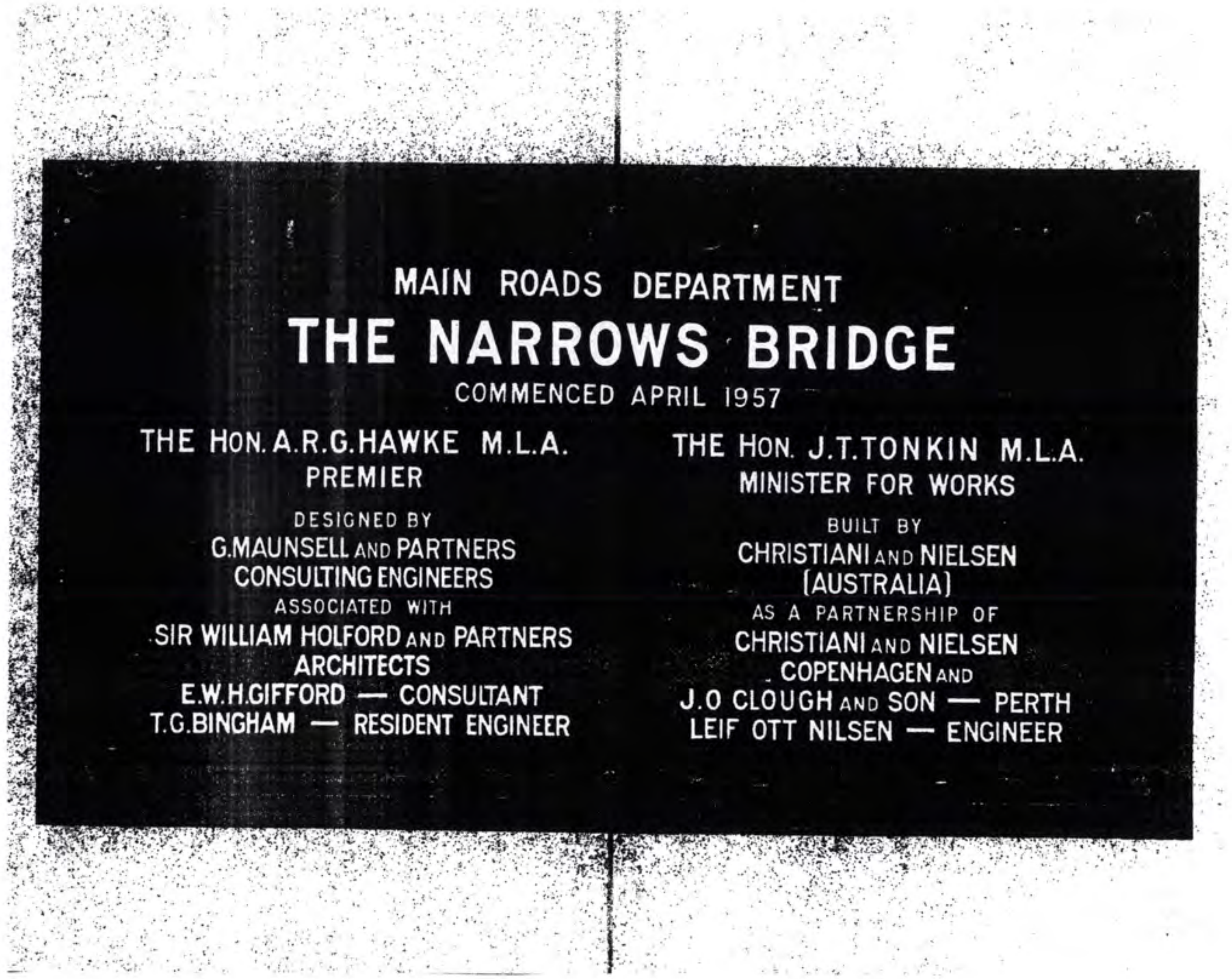


A VIEW THROUGH TWO PIER COLUMNS SHOWING THE FOUR TRIANGULAR COLUMNS OF A RIVER PIER SUPPORTING THE EIGHT LINES OF SUPERSTRUCTURE BEAMS.



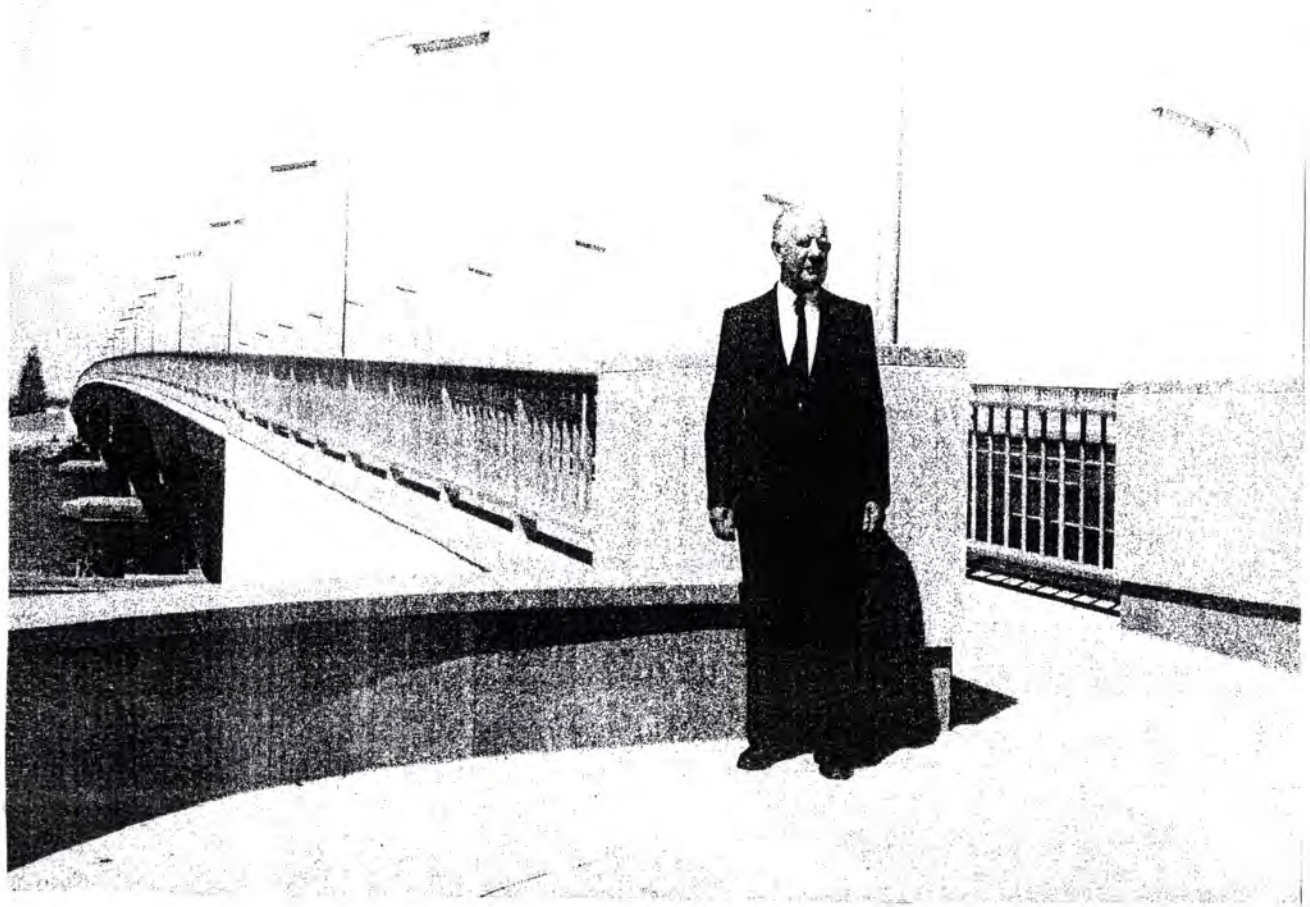
A GENERAL VIEW ALONG THE COMPLETED BRIDGE SHOWING THE FINISHED SURFACING BALUSTRADING, AND LIGHTING STANDARDS.

THE RIBBON IS CUT BY HIS EXCELLENCY. IN ATTENDANCE ARE THE MINISTER FOR WORKS, THE COMMISSIONER OF MAIN ROADS AND THE PREMIER. A BOY SCOUT AND A SEA SCOUT ASSISTED BY HOLDING THE RIBBON.



THE PLAQUE ON THE NORTH-WEST PILASTER
COMMEMORATING THE INCEPTION AND THE
BUILDING OF THE BRIDGE.

THE PLAQUE ON THE NORTH-EAST PILASTER COMMEMORATING THE COMPLETION AND OPENING.



E. W. C. GODFREY, B.C.E., M.I.E. AUST.

WHO CARRIED OUT THE EARLY INVESTIGATIONS AND WAS LIASION ENGINEER BETWEEN THE MAIN ROADS DEPARTMENT AND THE CONSULTANTS.

ATTACHMENT 2

ASSESSMENT OF SIGNIFICANCE

Extract From

Narrows Bridge Conservation Plan

Prepared for Main Roads Western Australia

By R. Bodycoat (June 1998)

NARROWS BRIDGE

CONSERVATION PLAN

Prepared for Main Roads Western Australia
by

RONALD BODYCOAT · ARCHITECT
104 Forrest Street, Cottesloe WA 6011

June 1998

CONTENTS

ASSESSMENT OF CULTURAL HERITAGE SIGNIFICANCE

1.0 INTRODUCTION

1.1 THE BRIEF

In June 1998, Main Roads Western Australia commissioned a Conservation Plan for the Narrows Bridge in the context of an option to widen the Bridge.

The primary purpose of the Conservation Plan is to clearly set out what is of cultural significance in the place, and determine what policies are appropriate to enable that significance to be retained in its future use and development.

The Conservation Plan is based on the recommendations set out in *The Burra Charter (Australia, ICOMOS)*, and JS Kerr's, *The Conservation Plan,* National Trust of Australia (NSW) 1990. The criteria on which assessment of cultural heritage significance has been made are those of the Heritage Council of Western Australia.

The Report, then, is divided into two parts:

1 the assessment of cultural significance , and

2 the Conservation Policy.

The place was inspected, assessed and photographed in June 1998.

1.2 DEFINITION OF THE PLACE

The Narrows Bridge is located across The Narrows, a narrow neck of the Swan River at the western entry to Perth Water, between Pt Lewis at the foot of Mt Eliza and Pt Belches on the South Perth promontory.

When built, both ends of the Bridge required some filling of the river to accommodate the abutments and in consequence the former shore line was re-aligned. Associated road interchange requirements at the northern end of the Bridge required major filling of the former Mounts Bay at the western end of Perth Water.

1.3 CURRENT SITUATION

The place has not been considered previously to determine any cultural heritage significance.

The Bridge has been in continual use since initial construction and its Official Opening on 13 November 1959.

The current proposal is to widen the Bridge to provide two dedicated bus lanes and additional traffic lanes to improve vehicular safety and reduce congestion.

1.4 OTHER ISSUES

Since 1959, the Narrows Bridge as a river crossing has successfully serviced the Freeway system which services the City of Perth and by-passes the City as the principal North-South traffic artery between centres North and South of the Capital, notwithstanding that at the time of its construction, public outcry sought to stop its construction. A river crossing, then, was publicly accepted in principle; major filling of the river for the necessary interchange road system at the City end of the Bridge, became the main focus of community concern.

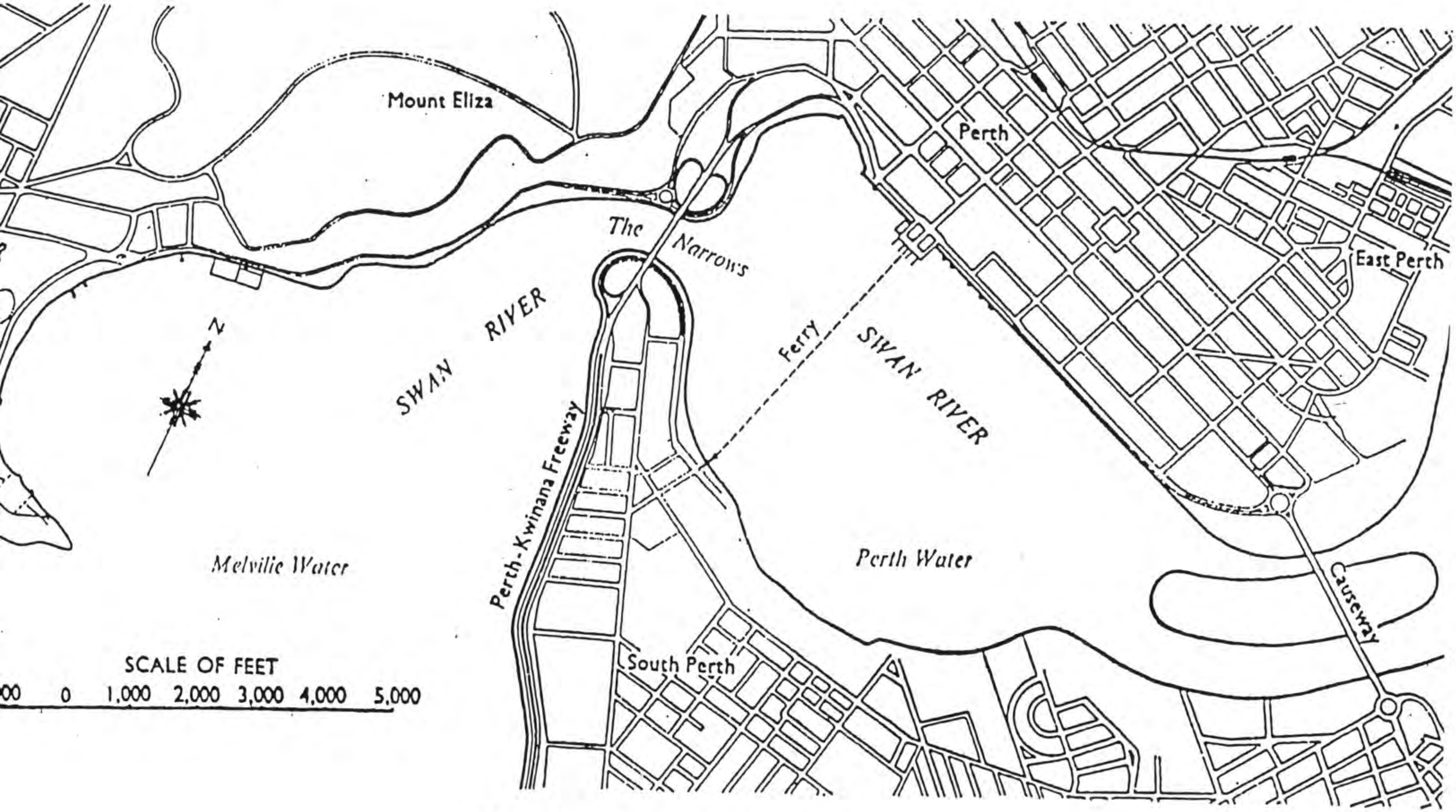
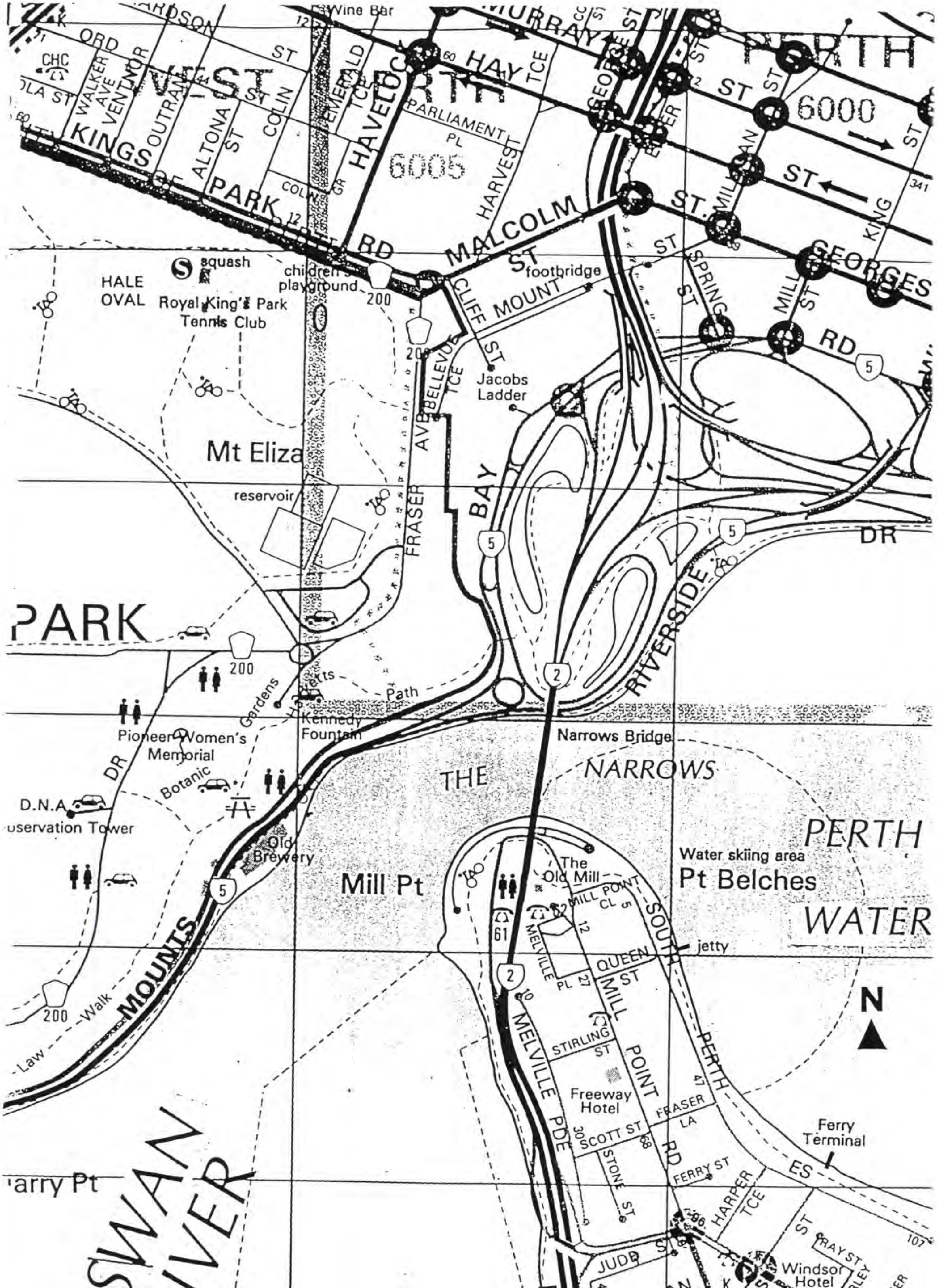
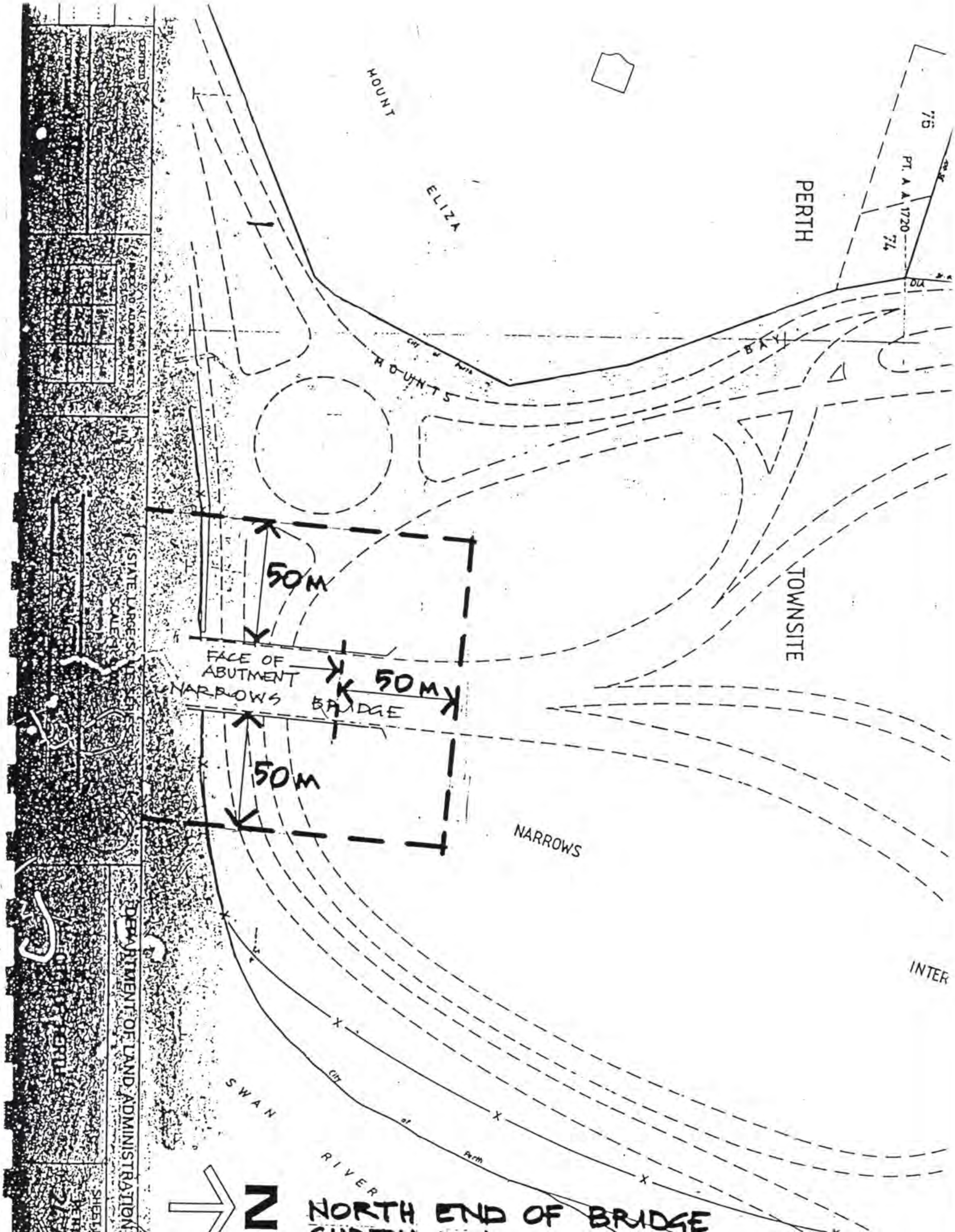


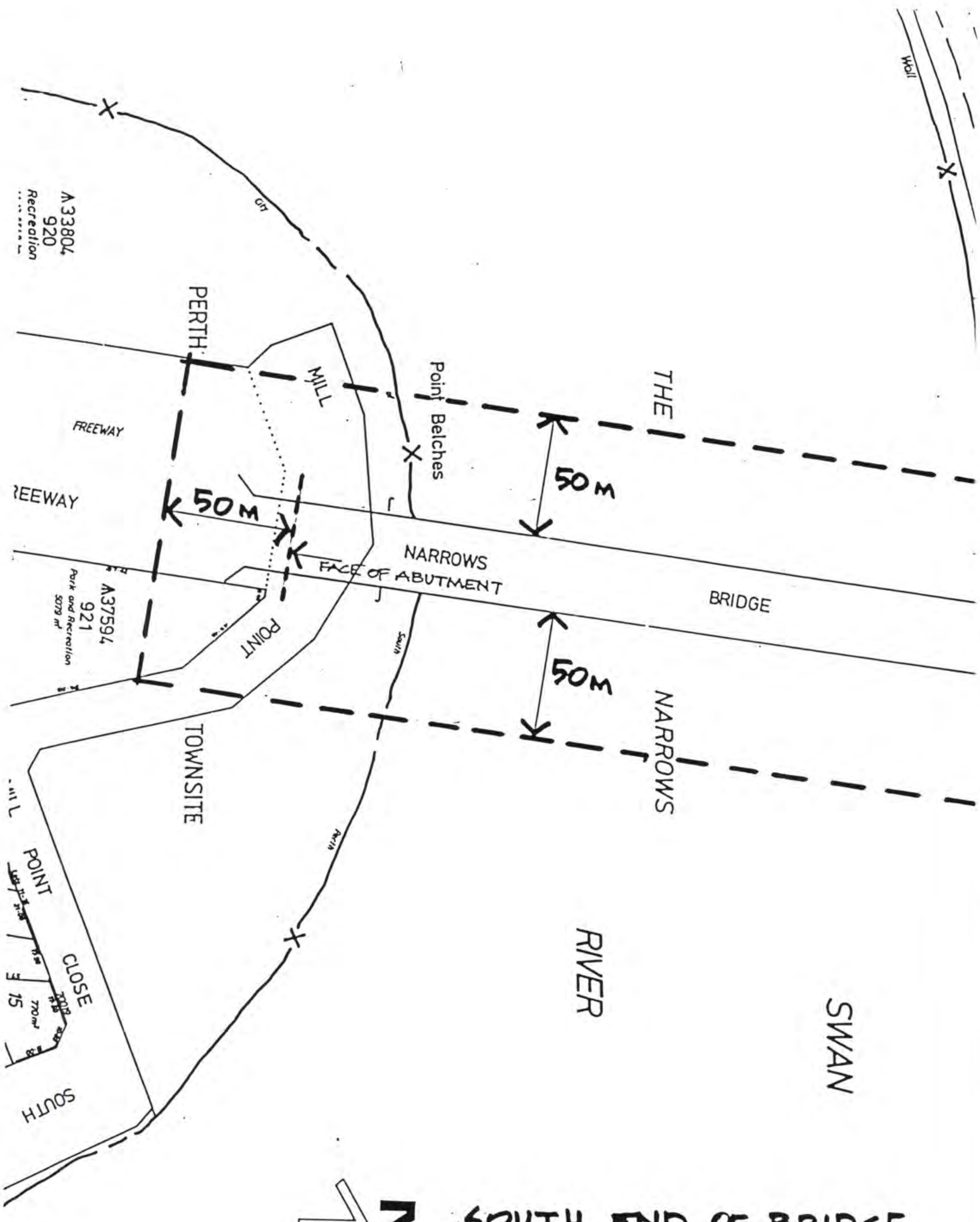
FIG. 1.—PLAN OF LOCALITY



Wine Bar
MURRAY
PERTH
WEST PERTH
ORD
ST
CHC
WALKER AVE
VENTNOR
OUTRAM
ALTONA ST
COLIN
EMERALD TCE
HAVELOCK
HAY
TCE
GEORGE ST
ST
6000
PARLIAMENT PL
6005
HARVEST
KINGS PARK RD
COLIN GR
MALCOLM ST
MILLIGAN
ST
KING
ST GEORGES TCE
SPRING ST
MILL ST
RD
5
footbridge
MOUNT ST
CLIFF ST
BELLEVUE TCE
squash
HALE OVAL
Royal King's Park Tennis Club
children's playground
200
Jacobs Ladder
Mt Eliza
reservoir
FRASER AVE
BAY
5
DR
RIVERSIDE
PARK
200
Path
Gardens
Kennedy Fountain
2
Narrows Bridge
Pioneer Women's Memorial
Botanic
DR
THE NARROWS
D.N.A. Observation Tower
Old Brewery
5
Mill Pt
The Old Mill
MILL POINT CL
PERTH WATER
Water skiing area
Pt Belches
61
MELVILLE PL
SOUTH
jetty
QUEEN ST
MILL
2
MOUNTS
200
Walk
Law
N
MELVILLE PDE
STIRLING ST
POINT
PERTH
Freeway Hotel
FRASER LA
SCOTT ST
STONE ST
RD
ESPLANADE
Ferry Terminal
FERRY ST
HARPER TCE
SWAN RIVER
JUDD ST
RAY ST
Windsor Hotel



MOUNT ELIZA
PERTH
PT. A.A. 1720
MOUNTS BAY
TOWNSITE
50M
FACE OF ABUTMENT
50M
NARROWS BRIDGE
50M
NARROWS
INTER
SWAN RIVER
STATE LARGE SCALE SERIES
DEPARTMENT OF LAND ADMINISTRATION
N
NORTH END OF BRIDGE



SOUTH END OF BRIDGE CURTILAGE

ANALYSIS OF CULTURAL HERITAGE

2.00 ANALYSIS OF CULTURAL HERITAGE SIGNIFICANCE

2.1 DOCUMENTARY EVIDENCE

Some original drawings and a collection of photographs taken during and after construction of the Narrows Bridge, together with detailed reports, signed agreements and newspaper reports are held in the Library of Main Roads Western Australia. From this extensive collection of data relating to all relevant aspects - from the decision by Government to build the Bridge to the status of the structure today - the following brief chronological account is extracted. Some of the documentation is included in Section 7 of this report at Appendices and References.

Chronological Evidence

1829 Settlement and Founding of the Town of Perth

1833 Shenton's first Mill was constructed on what is now known as Mill Point at Pt Belches on the southern side of the narrow neck in the Swan River between Perth Water and Melville Water. Shenton's second Mill, constructed in 1835, survives today adjacent to the southern abutment of the Bridge.

The opposite bank of the neck, now referred to as The Narrows, was named Pt Lewis, at the foot of the high ground of Mt Eliza, now King's Park. [1]

1834 A ferry service was established across the narrow neck from Pt Belches to the foot of Mt Eliza.[2] The route for land travel at that time was via Guildford, a considerably greater distance of 29 kilometres.

1843 The first Causeway Bridges were constructed across the Heirisson Islands at the eastern extremity of the Town and Perth Water. [2]

1849 An article in "The Inquirer", a Perth newspaper, commented on the desirability of constructing a bridge at the Narrows. Similar sentiments are recorded up to the turn of the century. The Narrows crossing would provide a line of communication between Perth and Fremantle in lieu of the existing tedious and protracted route via the causeway.[2]

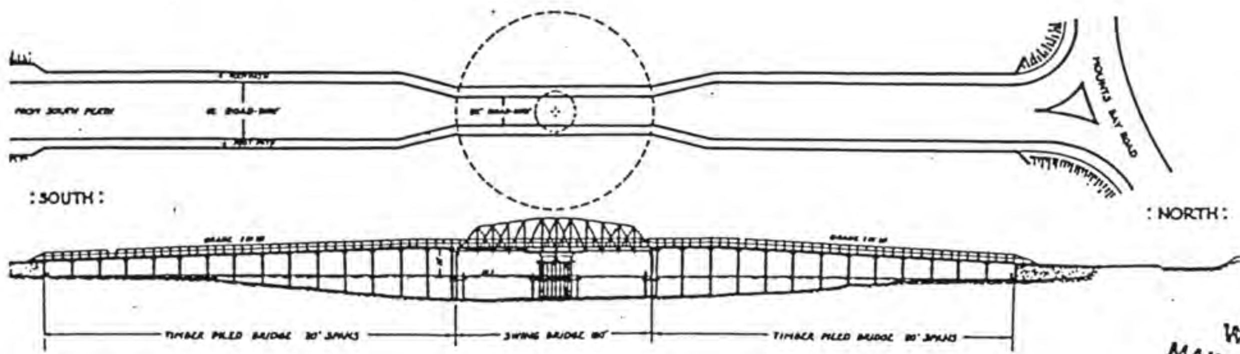
---

1 *Conservation Plan for the Old Mill, South Perth, Ronald Bodycoat 1993*

2 *Official Opening Booklet 1959. Government of WA*

1901 The sale of property at Mill Point in 1885 highlighted the possibility of a bridge being built at the Narrows.

The Public Works Department of the State Government produced a preliminary design for a bridge at the Narrows, consisting of a timber pile structure with a central navigation section achieved by a swinging steel truss. The time was not considered appropriate for such a structure and the plan was shelved. [2]



Plan and profile of proposed timber bridge and approach roads, designed by the Public Works Department in 1901, to cross the Narrows

1930 Consistent proposals for an alternative river crossing to the Causeway, prompted by vocal residents in South Perth over the years, were highlighted by a report by the Metropolitan Town Planning Commission noting in regard to a crossing at the Narrows:

"that this position affords a natural and necessary opportunity for linking both sides of the Swan River" [2]

1947-53 Preliminary reports and planning for a bridge at the Narrows were prepared by the Main Roads Department; no further action happened while resources were directed to construction of the new Causeway bridges at Heirisson Island.

Discussions did take place in 1953 however, with the Consultant, Professor Gordon Stephenson, preparing the Town Planning Scheme for the Metropolitan Region, to co-ordinate a new traffic crossing of the river. [2]

---

2 *Official Opening Booklet 1959. Government of WA*

1954 Traffic surveys by the Main Roads Department indicated that traffic on the Causeway had more than doubled in less than five years and that the Causeway rotaries and Canning Highway were approaching saturation. Investigation of the possibility of constructing a bridge at the Narrows was imperative. Government announced in August 1954 that preliminary site investigation work would commence at once. [2]

Preceding construction of the Bridge, 29 hectares of Mounts Bay was reclaimed to provide a future road interchange. [2]

1955 In 1955, the State Government sent Mr EWC Godfrey, Bridge Engineer for the Main Roads Department, overseas to inspect world-class bridges in similar locations and to recommend consultants to design, specify and supervise construction of a bridge across the Narrows. [2]

1956 As a result, in 1956 State Cabinet appointed Maunsell & Partners, Consulting Engineers in London to prepare schematic plans. The wide experience of this consultant in particular with regard to the difficult foundation conditions and design requirements, led to their appointment. [2]

1956 In January 1956 an Agreement was signed in London by the State of Western Australia and G Maunsell & Partners, Consulting Engineers. [3]

1956 Following a visit to Perth in December 1955 by one of Sir William Holford's partners, two alternative designs were prepared:

- a steel girder bridge completely clad in artificial stone
- a prestressed concrete bridge of less slender proportions.

William Holford had been appointed by Maunsell & Partners as sub-consultants. Prior to these design proposals, road and rail bridges in the State had been constructed using predominantly timber framework. At that time in 1956, the costs were estimated to be

- steel design £A2,173,000
- prestressed concrete design £A1,503,000..

Sir William Holford promoted the prestressed concrete design because it was potentially the most interesting and pleasing of the two designs.

---

2 *Official Opening Booklet 1959 - Government of WA*

3 *The State of Western Australia - Narrows Bridge, Perth Memorandum of Agreement, January 1956*

On the basis of lower cost and the consultant architect's view, Maunsell & Partners recommended to Government that the prestressed concrete design should be supported. [4] This new structural technique was new to bridge design in WA at this time.

1955/63 A review of the Narrows Bridge, 25 years on in 1984, records the following comments: [5]

"The decision to build the Narrows Bridge was taken when the Stephenson, Hepburn Report was being prepared in which the basic shape of the future City was outlined, including the future major road system. This concept was given strength when the MRS came into operation on October 30, 1963. Since then, projects undertaken by the MRD have aimed at developing the road system to provide a network of regional roads which will provide safe and rapid access throughout the Metro area taking much of the heavier traffic flows and many of the heavier transport vehicles out of the metro street system."

"Because of its youth, it is possible for the (Perth) Metro Region to have a road system superior to those of nearly all other great cities, but it will require fairly immediate action if future possibilities are to be reserved".

G Stephenson & JA Hepburn 1955

"In this 1955 Report (Stephenson & Hepburn Report 1955), on a plan for the Metropolitan Region, Perth and Fremantle, Stephenson & Hepburn threw down the challenge that was to be picked up and acted upon by the MRD of WA.

(Alistair Hepburn - WA's Town Planning Commissioner 1953-59).

In the mid 1950s the State was emerging from its "Cinderella" status and was approaching a period of rapid economic growth. Those with vision could foresee the future demands that would be placed on the State's capital city, particularly the pressures that would arise from a rapid increase in population."

---

4 *Report on the Narrows Bridge, Perth (to the Commission for Main Roads), April 1956*
G Maunsell & Partners, Consulting Engineers
Sir William Holford & Partners, Consulting Architects

5 *Western Roads, November 1984 - Journal*

"Once the concept for city growth had been accepted, a decision was made to build the Narrows Bridge, the central and most vital link in the future regional road system. This led to the adoption of a simple strategy by the MRD whereby:

1 Work would be undertaken to the north and south of the Narrows Bridge, working outwards into the centre, to full freeway standards.

2 Available funds would be allocated to ensure that the balance of the major road network would be developed in stages as the need arose."

It is of interest to note that the official accounts published for Government record some of the public sentiment about the project at the time:

> *"There is some dissent with the Department's proposals to reclaim 19 acres of the river to accommodate the important interchange required immediately north of the Narrows Bridge."* [6]

The project was seen by its critics to be :

"too ambitious"
"vandalism"
"Mounts Bay trees will be cut down"
"the Old Mill will be destroyed"
"the river will be destroyed"
"tunnel under King's Park". [7]

1956 Cabinet approved the proposal on 1 May 1956. **Aesthetic features** were accepted as important on the advice of Professor Gordon Stephenson, Town Planning Consultant to Government, who emphasised that the visual impact of the Bridge was paramount. The outcome was a deck-type structure of 6 lanes in prestressed concrete in five spans, the centre span to be 320 feet with two flanking spans each 230 feet, all across the waterway, plus spans at each end of 160 feet over underways on land for road traffic. The Bridge was intended to carry a capacity of 6000 vehicles per hour in one direction. [8]

---

6 *Report on the Narrows Bridge, Perth April 1956*
G Maunsell & Partners

7 *Western Roads, November 1984*

8 *The Narrows Bridge - Baxter & Gifford 1961*

1957 In March 1957, a contract was awarded, following the submission of detailed design, to the construction company Christiani and Nielsen of Copenhagen, Denmark in association with Western Australian Contractors J.O. Clough & Son, for an amount of £1,325,002 ($2,650,005,) a huge sum in 1957. [8]

1957 The first pile was driven on August 14, 1957.

Two important changes to the initial Bridge design were incorporated

- the site layout and the design loading.

The intended shorelines of the reclamation area of the river at the time of the consulting engineer's appointment would have resulted in a skew Bridge - minor realignment eliminated this element considered to be undesirable.

The adjustment resulted in a more aesthetically pleasing result and avoided greater complexity of design and construction.

The Bridge design loading was changed from the proposed Australian Standard Bridge Design Loading to BS 153, as a more appropriate standard. [8] The Australian Standard was derived from the American Association of State Highway Officials Standard in use in North America which was considered arbitrary in that loading is not made sufficiently dependent upon span, whereas the British Standard is a more logical interpretation of probable actual conditions and so can be applied in proportion to local requirements.

1959 Deputy Premier Tonkin announced on February 10, 1959 that the new Bridge across the Narrows would be called the **Golden West Bridge** and the freeway to Canning Bridge would be styled the **Golden West Freeway.**

In response to strong public opposition to this naming the new Liberal-Country Party Cabinet changed the naming to **NARROWS BRIDGE.** [9]

1959 **The Narrows Bridge was completed and officially opened on 13 November 1959 at 10.30a.m.** The opening Plaque mounted on the Bridge abutment and the booklet published by Government for the opening ceremony record the following data: the plaque was unveiled by the Governor:

<u>Governor</u> - His Excellency Sir Charles Gairdner

<u>Premier</u> - The Hon. D Brand, MLA

<u>Minister for Transport</u> - The Hon. CC Perkins

<u>Minister for Works</u> - The Hon G.P. Wild, MBE

<u>Commissioner for Main Roads</u> - Mr J Digby Leach.

Description of Materials and Construction

The materials and construction are summarised as follows:

MATERIALS

Piled Foundations

180 total Gambia piles comprising 806mm outside diam. steel tubes terminating in a conical steel toe; filled with reinforced concrete and driven into the sands, silts, gravels and clays forming the river bed, and grounded on very hard clay overlaying a limestone stratum. Pile lengths vary from 27m to 38m approx.

Pile Caps

Reinforced concrete faced with precast concrete panels.

Columns

Four columns to each pile cap, of reinforced concrete, three of every four supported on stainless steel bearing plates and cast steel rollers.

Abutments

Box type reinforced concrete carried on piles.

Deck Structure

8 I-section double cantilever beams precast in short lengths, diaphragms, and external stranded prestressing cables
concrete road deck.

Superstructure details

precast exposed aggregate side panels
anodised aluminium balustrading and safety fencing
aluminium lighting standards.

CONSTRUCTION

Construction extended from March 1957 until September 1959. Underground and below water works in foundation construction were eliminated and the superstructure was precast on shore at the southern end of the Bridge.

Beam erection, jointing and stressing was carried out on an extensive timber staging supported upon jarrah and karri piles driven in the river.

A travelling gantry in the casting yard delivered precast units to a railway on which the units were transported along the full length of the Bridge. A second gantry straddling the staging on which the Bridge was erected and the railway running alongside, served to lift the units into position.

Post 1959 **Physical Changes to the Bridge 1959 - 1998**

In recent years, since completion of the Bridge in 1959, Main Roads WA has maintained the structure in sound condition, monitored the performance of the structure and carried out changes to accommodate the growth in traffic and public transport, to upgrade the lighting installation and to strengthen the structure and upgrade protection to the pre-stressed cabling, as follows:

- removal of the western pedestrian way in order to provide a central peak/bus lane
- strengthening of the pre-stressed cables and upgrading of protection of the cables
- renewal of road surfacing
- replacement of lighting highlighting the eastern and western faces of the Bridge structure
- replacement of lighting standards and lamps fitted to the extremities of the Bridge standards.

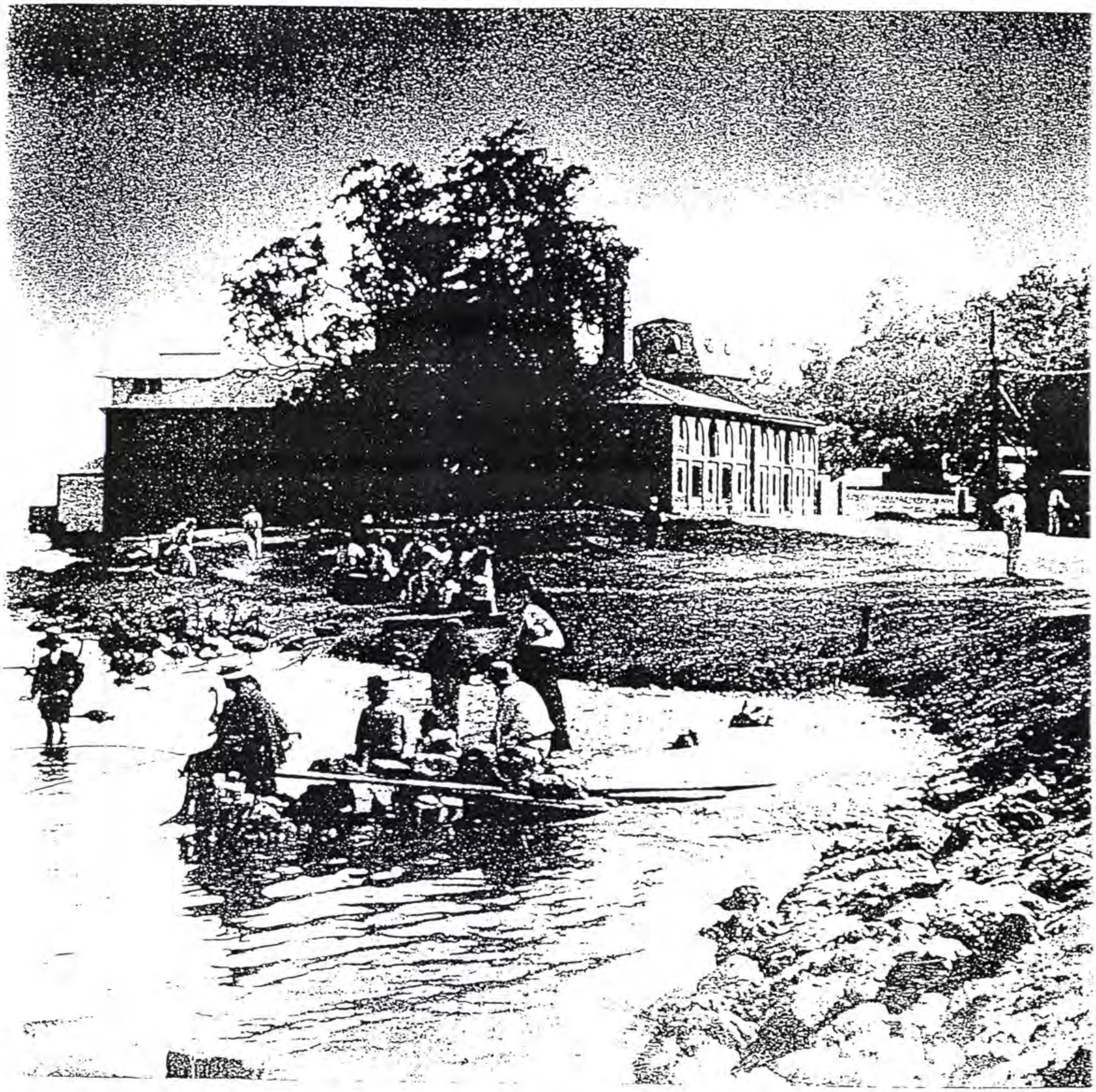
1998 **The Narrows Bridge** is now a critical element in the freeway system which currently links Kwinana in the South with Joondalup in the North. Other road networks service the City of Perth and become part of the traffic system servicing the Metropolitan Region; the network focusses on the Narrows Bridge as a high traffic volume river crossing.

Urban expansion within and beyond the Metropolitan Region now means that the Narrows Bridge no longer adequately serves the expanded road system. Statistics show that the community is a car-oriented population; public transport is promoted by government, but is not necessarily well patronised by the community.

An increase in population densities in the Metropolitan Region and improvements to public transport, decentralisation and a highly mobile community together mean that key elements in the road system, such as the Narrows Bridge, need to be reviewed and adjusted.

1998 Government has announced a proposal to widen the Narrows Bridge in order to provide two discreet bus lanes, in support of enhancement of public transport on the Freeway system of which the Bridge is an important element; additional general vehicle lanes to accommodate the growth in traffic using the crossing and the freeway system; and to facilitate a safer interchange system at the northern, city end of the Bridge.

HISTORIC PHOTOGRAPHS[1]



The historic 19th century ambience of the River at the Swan Brewery, close to the Narrows.

The Brewery survives today, in changed form; the former peace and leisurely enjoyment of the River has been challenged by the changes in transportation and population density.

"The Streets of Old Perth"

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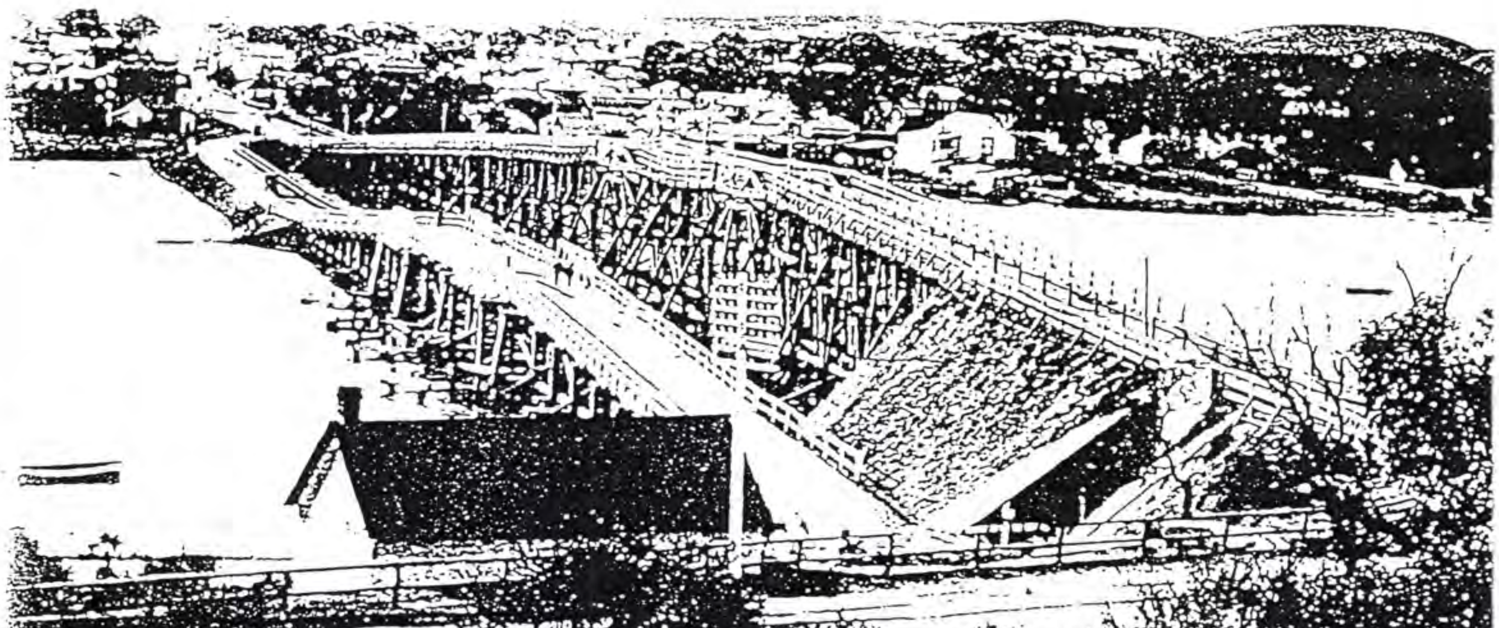
[1] "The Streets of Old Perth"

DOCUMENTARY EVIDENCE Cont'd

HISTORIC PHOTOGRAPHS

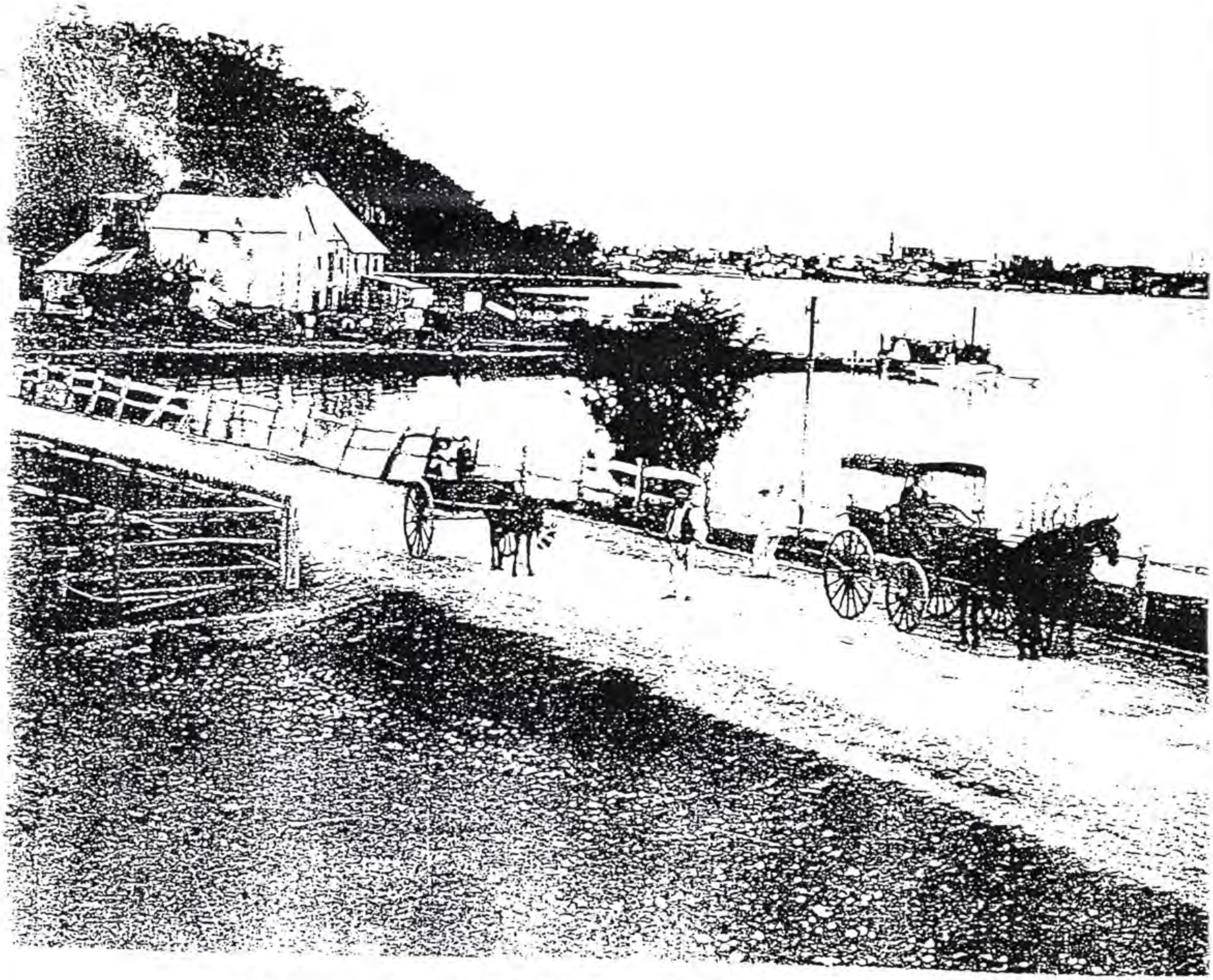


Timber-framed bridges across the Swan River at Fremantle - 1898 Photo

This method of construction formed the structural precedent to the concrete Bridge across the Narrows in the late 1950s.

"The Streets of Old Perth"

HISTORIC PHOTOGRAPHS



The Brewery, Mt Eliza and the Town of Perth beyond in the 19th Century.

This is the historic context for the Bridge of the 1950s which epitomises the change which growth in time produced.

"The Streets of Old Perth"

DOCUMENTARY EVIDENCE Cont'd

HISTORIC PHOTOGRAPHS

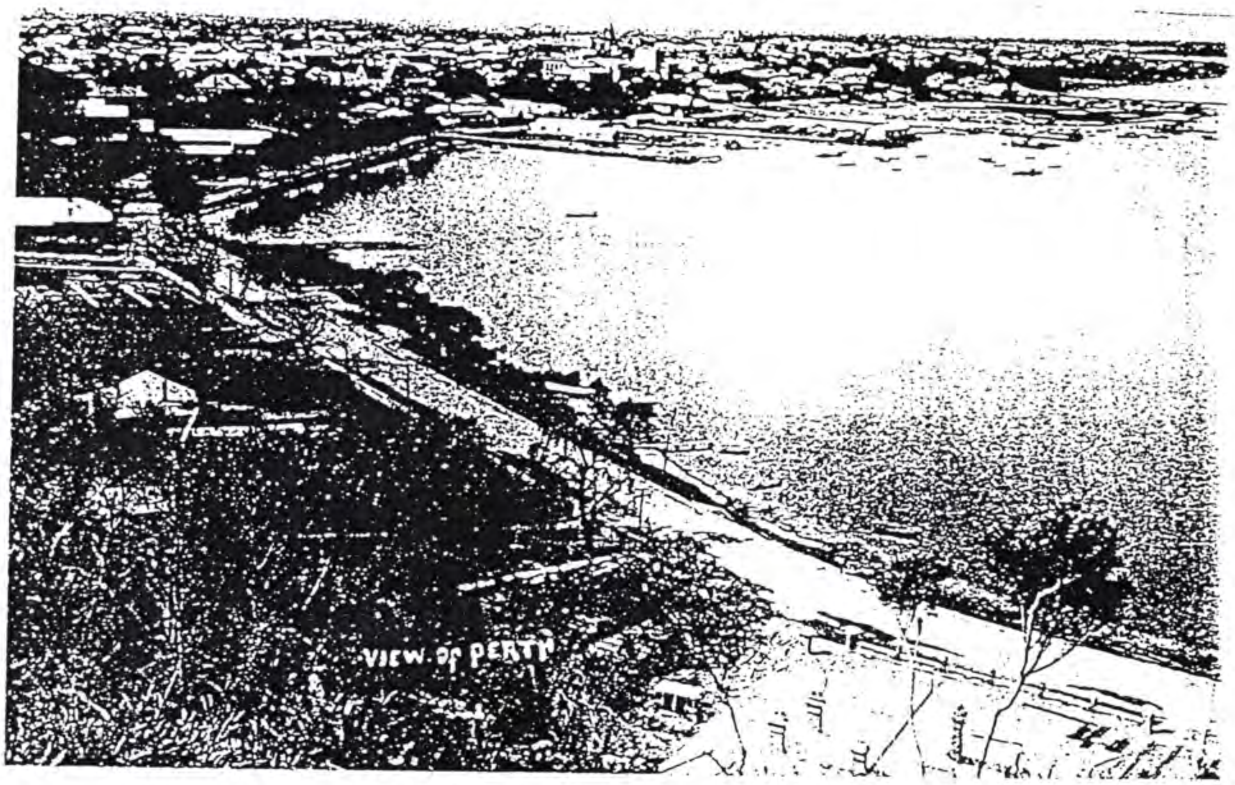


Fig. 12.4 Perth from Mt Eliza, c 1897

Perth water in the late 19th Century -

a tranquil yet busy means of transportation for goods and people.

" Western Towns & Buildings"

"Western Towns & Buildings"

DOCUMENTARY EVIDENCE Cont'd

HISTORIC PHOTOGRAPHS

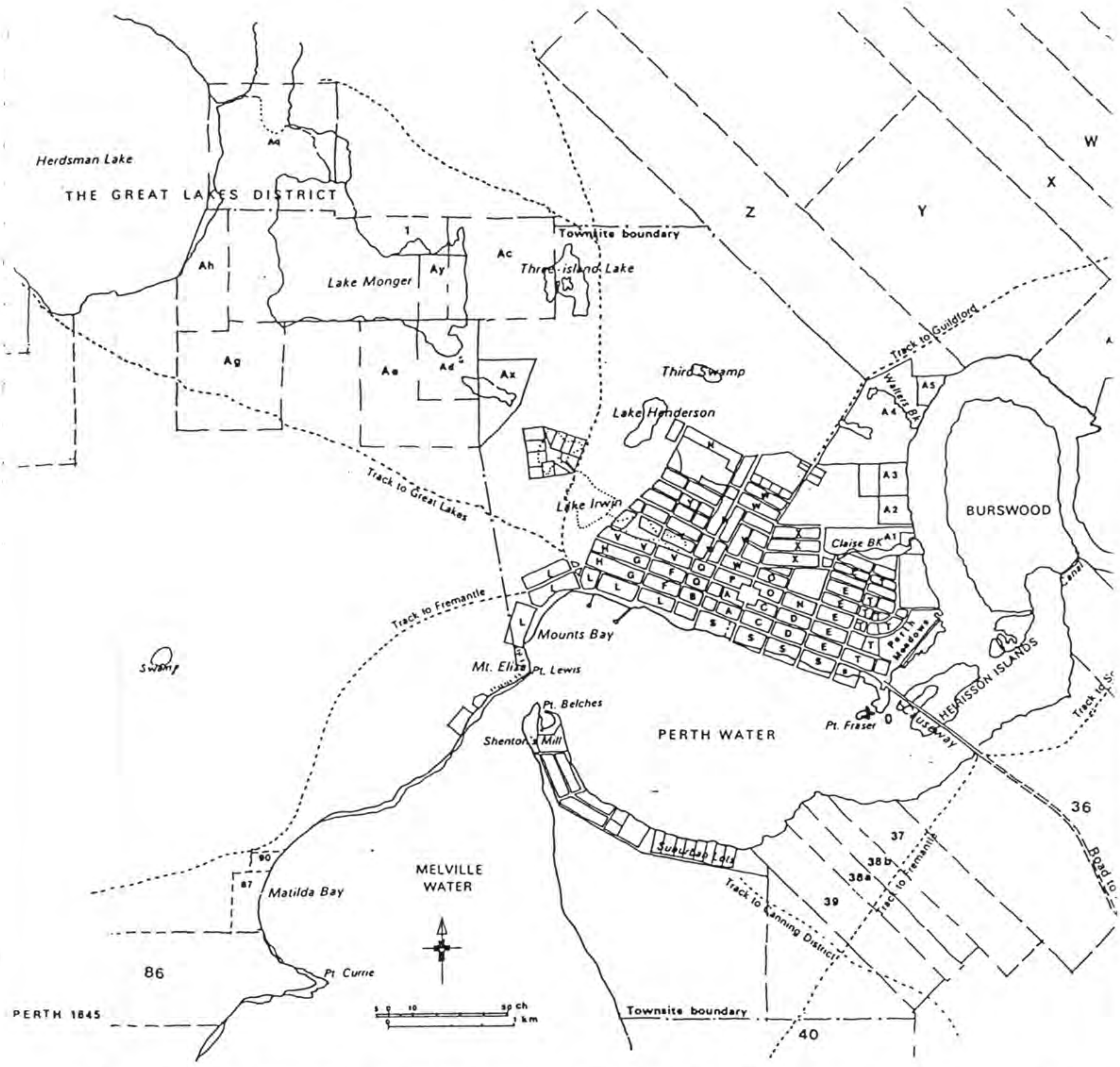


Fig. 1.11 The Town of Perth, based on the survey by A. Hillman, assistant-surveyor in 1845. This survey enabled by Act of Council 8 Vict. No 8 1844, was signed in the Executive Council on 22 July 1845 by the governor, John Hutt

Perth 1845 - with the Original features of the narrow neck between Melville Water and Perth Water - the neck which in the 1950s became the location for a river crossing.

"Western Towns & Buildings"

2.2 PHYSICAL EVIDENCE

An examination of the physical evidence of the Narrows Bridge reveals the following characteristics:

2.2.1 Architectural Style:

The Narrows Bridge derives its style from the structural engineering ingenuity developed in Europe and America in the 1950s. The pre-stressed concrete structural characteristics of this form and the details of the Bridge are international, as a consequence of the involvement of Maunsell and Partners, Consulting Engineers and Sir William Holford and Partners, Consulting Architects in the United Kingdom, governed by the pre-requisite in the Stephenson/Hepburn Brief that aesthetic constraints must apply to the physical characteristics of the structure.

It is important to note that as a consequence the Narrows Bridge set a standard for bridge design in the Perth region - aesthetic considerations, pre-stressing of the concrete structural frame, innovative design of piles to support the framework of the Bridge in difficult foundation conditions.

Bridges constructed in Western Australia since the Narrows Bridge of 1959 show a strong consideration for aesthetically appropriate design and a preference for concrete as the structural system. Examples of note are as follows:

- Mt Henry Bridge
- Shelley Bridge
- Stirling Bridge
- Redcliffe Bridge
- Mandurah Estuary Bridge
- Port Bouvard Bridge.

2.2.2 Accommodation:

The Bridge provides three lanes of traffic in two directions on a single level roadway, a central peak lane, and a two-way pedestrian/cycle way on the eastern edge. The structure spans the river in three arches, with an additional arch at each extremity over pedestrian pathways and roadways servicing access to and from the Bridge.

2.2.3 Development And Change

For changes to the Bridge since 1959, refer to Section 2.1 Documentary Evidence.

2.2.4 Schedule of Finishes

The following finishes apply to the elements of the Narrows Bridge:

. road surface	bitumen hotmix on a concrete sub-deck
. balustrading & safety fencing	anodised aluminium tubing
. lamp standards	tapered aluminium tubing
. edging facing to the Bridge structure	precast, exposed aggregate concrete panels
. soffit of the Bridge structure and pier columns	Off-form grey concrete
. abutments	exposed aggregate in-situ concrete walling
. special features at the pedestrian access to the Footbridge	polished granite facing panels

2.2.5 Description of Materials and Construction

Refer also to the Reports in the Appendices, Section 7.0 of this Conservation Plan.

The pre-stressed concrete Bridge was designed by Maunsell and Partners and constructed by Christiani and Nielsen in conjunction with J.O. Clough & Son Pty Ltd.

The form of the Bridge survives today with little change to the appearance of 1959 - a concrete structure of five spans supported on concrete columns in groups of four on a concrete base above river level, spanning the river at the Narrows.

Precast exposed aggregate side panels appear on the east and west faces of the superstructure with anodised aluminium balustrading and safety fencing and aluminium lighting standards on the eastern edge of the Bridge.

The Bridge provides six traffic lanes, three in each direction, a central bus/peak lane and a pedestrian footway/cycleway along the eastern edge.

DESIGN

The Narrows Bridge is a precast, prestressed concrete, continuous, five-span structure 335 metres between abutments having a central span of 97 metres flanked by spans of 70 and 49 metres.

The Bridge decking carries seven lanes of vehicular traffic, three in each direction with a reversible central peak/bus lane and a pedestrian footway along the eastern edge. Originally the Bridge provided six lanes, three in each direction, and a pedestrian footway on each side of the Bridge.

2.3 DISCUSSION AND COMPARISON

Documentary evidence in photographs, reports and Newspaper accounts has validated the origins and date of development of the Narrows Bridge and the form and appearance to be seen on site today.

The documentary evidence exists in the Library of Main Roads WA and Government files recording the process relating to the decision to construct the Bridge, the commissioning of consultants and contractual agreements, the two initial design proposals accompanied by sketch designs, argument and costing, and the various comprehensive reports prepared by Government at the time and subsequent to the opening of the Bridge. Copies of the original calculations, drawings and specifications are likely to survive in the records of the consultants in the United Kingdom.

Authenticity of design and construction derives adequately from a comparison of the above documentary data and the evidence provided by examination and assessment of the fabric to be discovered on site.

The Narrows Bridge is a five span pre-stressed concrete Bridge, supported on tapering concrete columns in groups of four supported on concrete bases at river level. The balustrading, lighting standards and finishes to the sides of the Bridge and the abutments appear as described in the documentation. The loss of one pedestrian walkway on the western side is apparent, as is the consequent introduced bus/peak lane in the centre of the Bridge.

Apart from cosmetic deterioration due to water seepage, reticulation staining and vandalism (graffiti), the condition of the Bridge appears to be sound. The extent of original fabric or changes to that fabric is listed in Section 2.1 Documentary Evidence - Post 1984.

The setting of the Bridge has changed on shore from the condition recorded in photographs taken at the time of completion of the Bridge in 1959 as the result of maturity of the landscape - tree planting, ground cover and ponds.

A comparison between the Narrows Bridge and other concrete bridges constructed since 1959, indicates a similarity in the pre-stressed structural design characteristics, the slenderness of design, the attention to aesthetics and appropriateness to the particular setting.

CULTURAL HERITAGE

The following explanation of heritage in the Australian context is relevant as the basis to determine the cultural heritage significance of the **NARROWS BRIDGE.**

Australia's heritage *includes those places and events which define and sustain the Australian character and provide a living and accessible record of the Nation's natural and cultural history. It represents the important examples of our natural environment and landscapes, the places which define the critical moments in our development as a Nation, and the achievements, joys and sorrows in the lives of our varied inhabitants.*

Australia's heritage comprises places, objects, events, cultural practices, stories, records and intangible values which reflect Australia's biophysical diversity and its cultural diversity - indigenous and non-indigenous.

Natural places *are defined as those sites, areas or regions where the "natural" biological, geological and/or other physical features are still largely intact.*

Historic places *are defined as those sites, areas or regions where the natural environment has been replaced or substantially altered by post-1788 human activities, or where there are strong human associations with natural areas due to past or ongoing human events or practices.*

Indigenous places *are defined as those natural or historic sites, areas or regions which have cultural significance for Aboriginal peoples or Torres Strait Islanders.*

Cultural heritage *includes places of both indigenous and historic heritage significance.*

Conservation *is defined to include protection, maintenance and preservation of places, and encompasses the concepts of statutory protection and appropriate resourcing for ongoing management.*

Extracts from:

Australian Heritage Commission
"A Future Heritage Places Regime for Australia" May 1997

2.4 PHOTOGRAPHS

The following colour photographs record the status and external characteristics of the Bridge in June 1998, its landscape and river context and the associated interchange and freeway connections.

They also record the presence of the Narrows Bridge in the context of the City of Perth.

Deterioration and other defects are identifiable in the photographs.

STATEMENT OF SIGNIFICANCE 3.0

The NARROWS BRIDGE

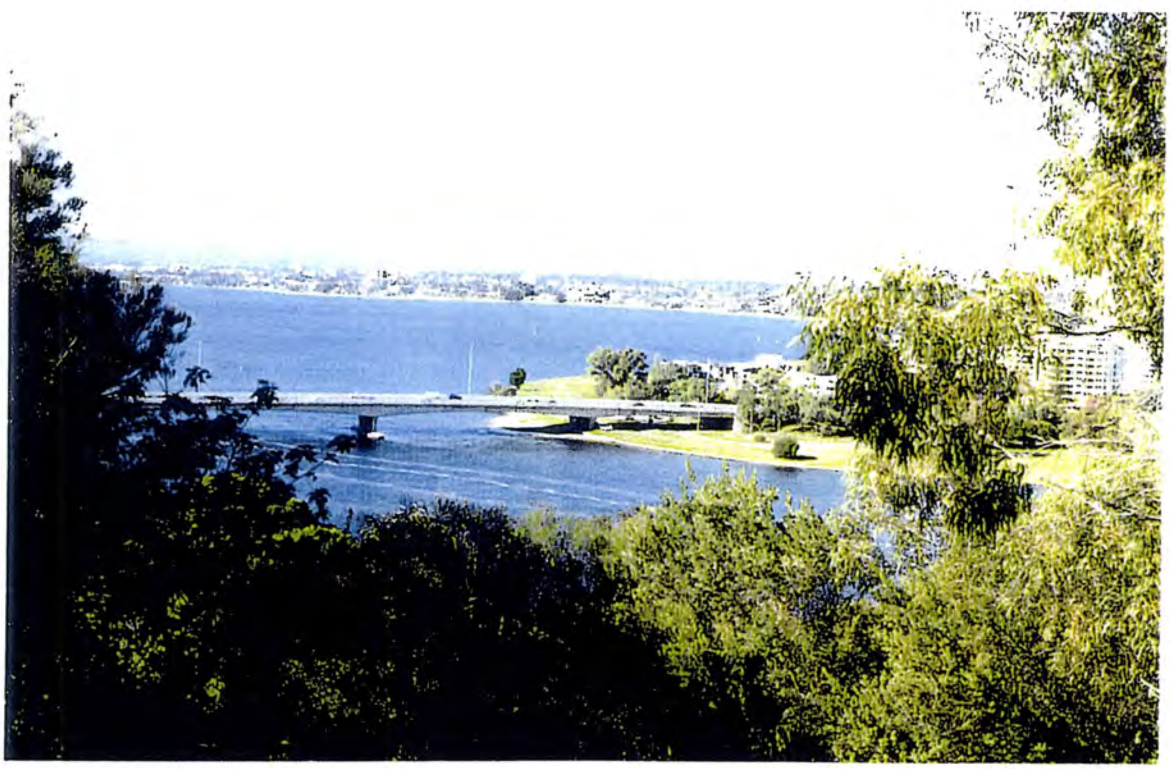
Viewed from downstream, Mt Eliza on the left and the City of Perth beyond.

The Bridge appears as *one* of the visual elements in this sublime landscape.

The Bridge as viewed from King's Park

The landscaped Northern interchange and the City beyond.

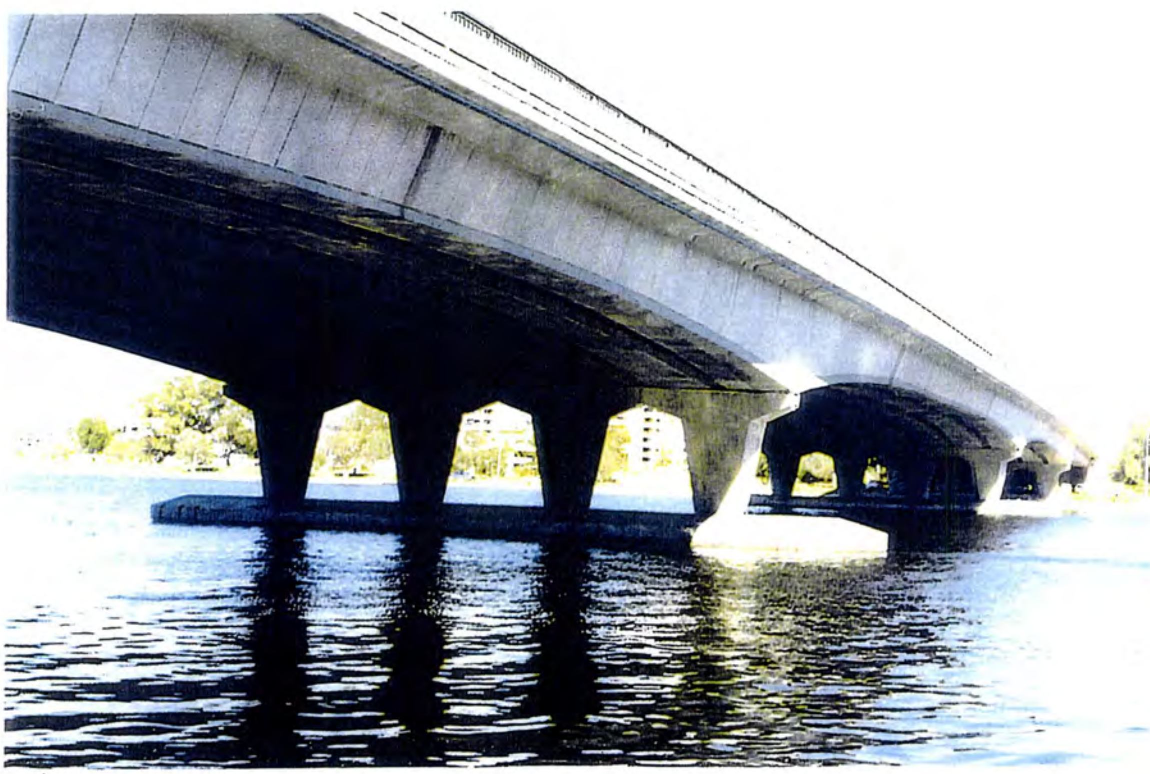
The Northern abutment



The Southern abutment

Viewed from King's Park

East face

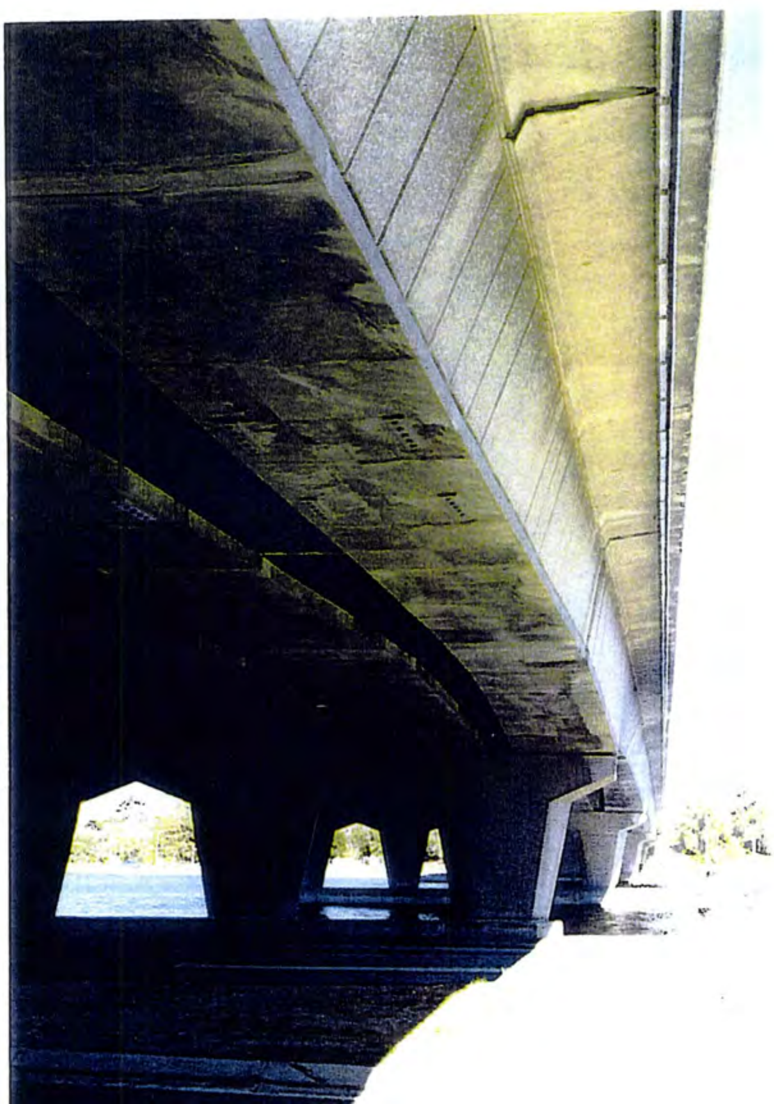


West face looking South

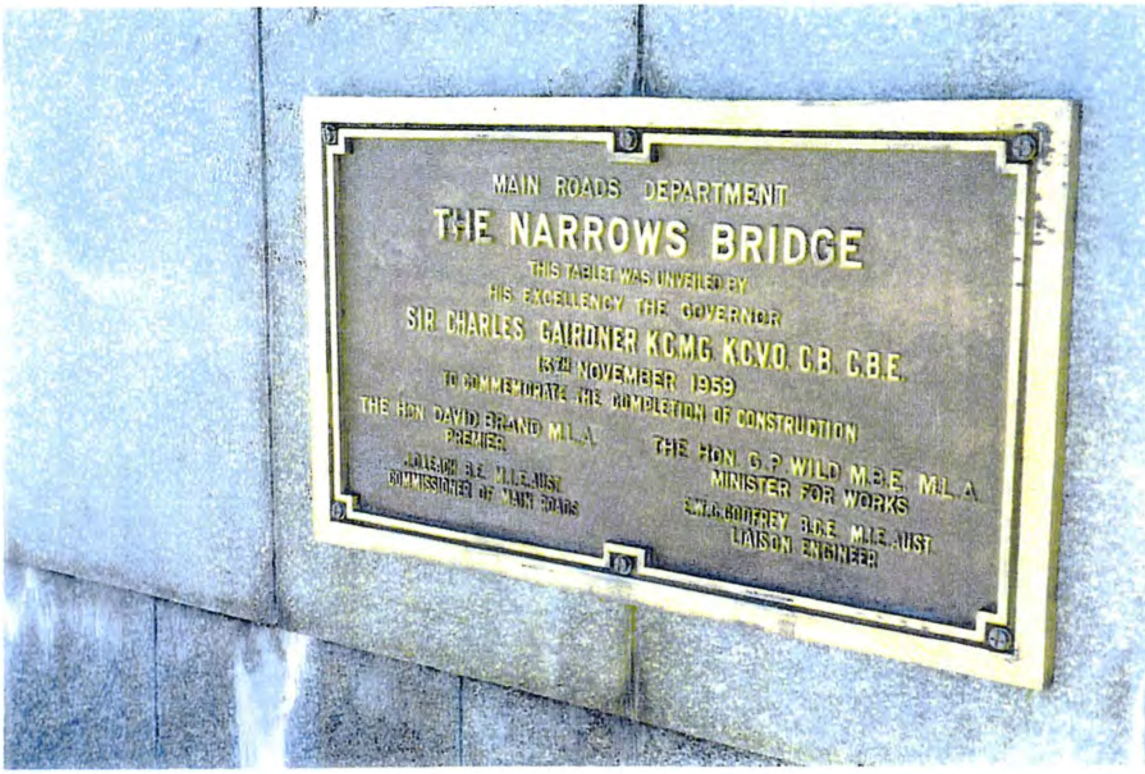
Eastern face at the Footbridge

Footbridge looking South

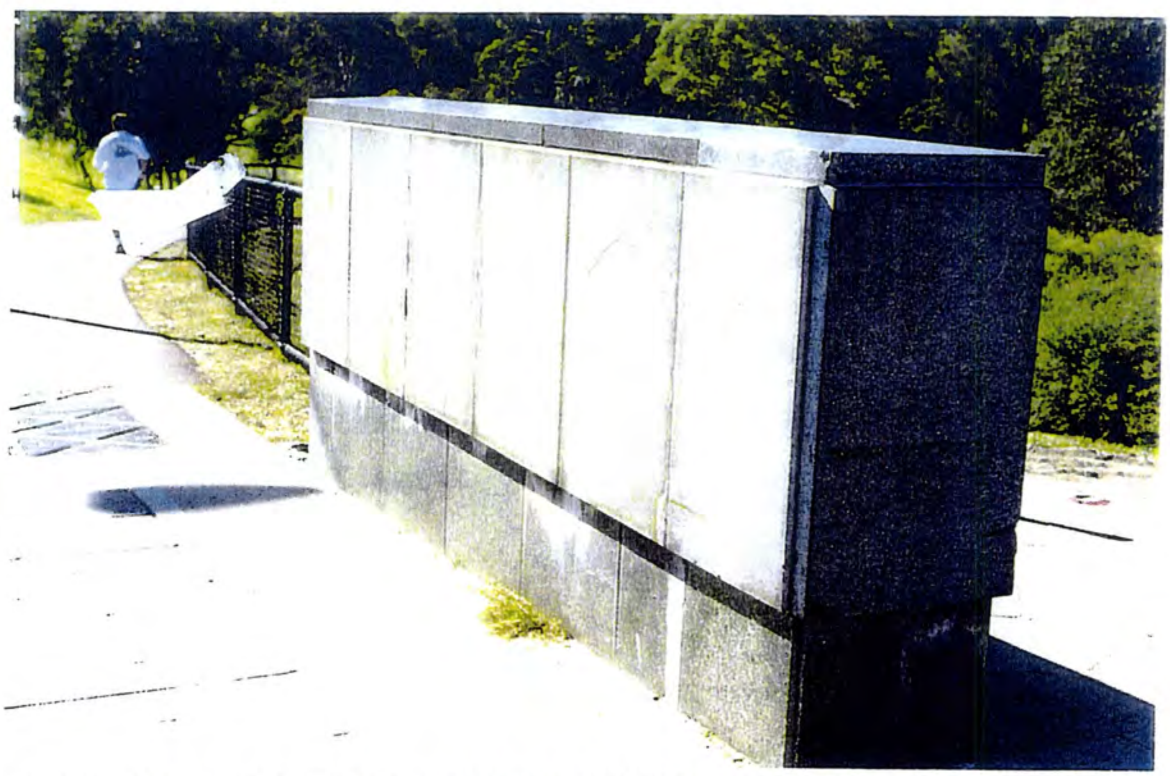
The roadways and pedestrian/cycle path and associated signage on the North side



Bridge soffit looking South



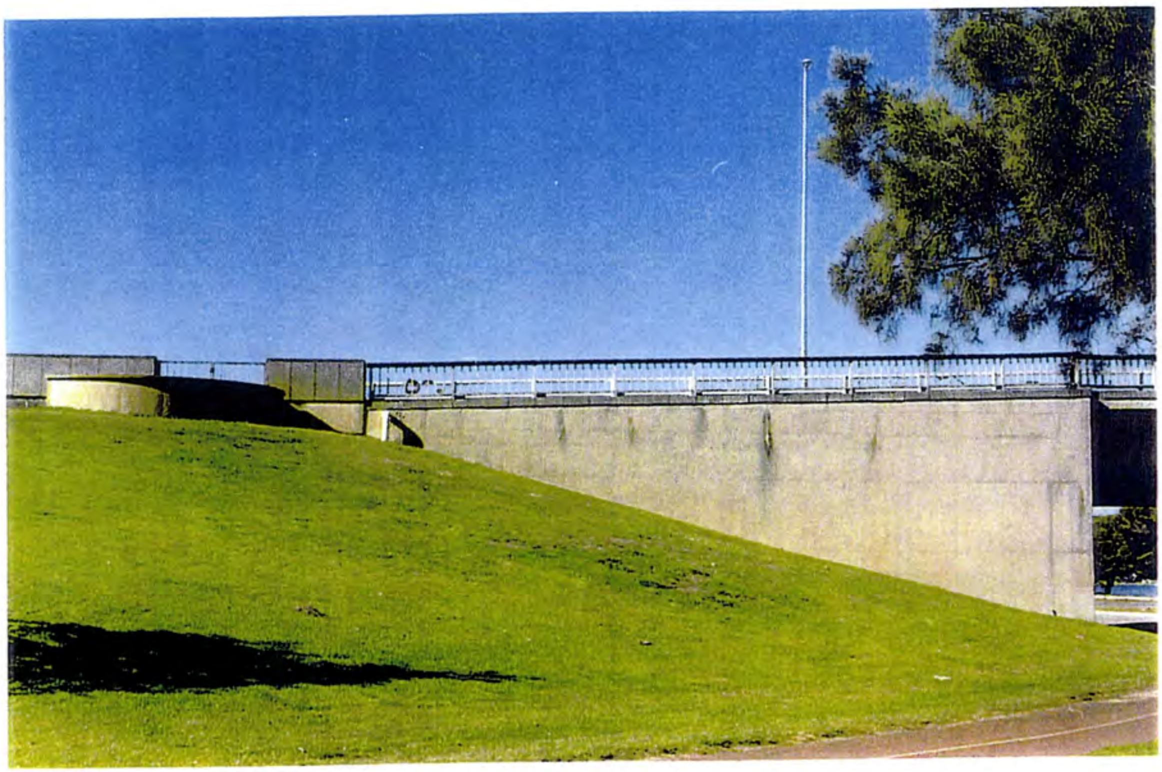
Opening Plaque and adjacent deterioration



Deteriorated granite facings at the Northern pedestrian entry to the footbridge

Water staining,
graffiti, repairs
and deteriorated
stone banking at
the North abutment.

Deteriorated paving and kerbing at the Northern abutment



Leaching and water staining at the Northern abutment

3.0 STATEMENT OF SIGNIFICANCE

3.1 ASSESSMENT OF SIGNIFICANCE

The criteria used in this assessment of significance are those set down by the Heritage Council of Western Australia in ***Criteria for Entry in the Register of Heritage Places,*** 16 November 1996.

AESTHETIC VALUE

The **NARROWS BRIDGE** is important for its value in exhibiting particular aesthetic characteristics. In conformity with the requirements of the original Brief and the advice of Professor Gordon Stephenson, Town Planning Consultant to the Government, the Consulting Engineers, G Maunsell & Partners in the U.K. and the Consulting Architects, Sir William Holford and Partners in the U.K., emphasised the need for aesthetic consideration to be incorporated into the design of the Bridge.
Criterion 1.1

The form of the structure in pre-stressed concrete was innovative in bridge design in Western Australian in the 1950s.
Criterion 1.2

The structure is seen to be a strong but unobtrusive element of the visual landscape comprised of the built form of the City and the Narrows Bridge and the natural form of the river and Mt Eliza.. The Bridge displays landmark values in the context of Perth Water and the river beyond and provides vistas down stream and eastwards to the Darling Range.
Criterion 1.3

The same visual resolution is apparent during the day and at night time in the context of an illuminated City and Bridge.
Criterion 1.4

HISTORIC VALUE

The **NARROWS BRIDGE** through its completion in 1959 as a road crossing at the Narrows, is important in the recent history of the development of the City of Perth. The Bridge is significant as an element in the evolution of Freeway road systems in the State and as an element of the Perth Metropolitan Region Scheme developed for the State Government by Hepburn and Stephenson in the 1950s.
Criterion 2.1

The Bridge is important historically as the eventual road crossing built in 1959 across the Narrows, the narrow neck between Perth Water and Melville Water, and originally contemplated in the 1830s.
Criterion 2.2

The Bridge is significant in a social history context through origins with the Hawke Government and with Works Minister, Tonkin, at the time of its design in 1954 and commencement of construction in 1956, with the eminent Consulting Engineers, Maunsell & Partners and Consulting Architects, Sir William Holford and Partners, as an element of the Stephenson, Hepburn Metropolitan Region Scheme of the 1950s, and subsequently with H.E. the Governor of the day, Sir Charles Gairdner who opened the Bridge and with the Hon. David Brand then Premier and J Digby Leach then Commissioner of Main Roads.
Criterion 2.3

The Bridge is one element of the Freeway System which originated to service the City and Metro Region in the 1950s and continues in operation today.
Criterion 2.4

SCIENTIFIC VALUE

The **NARROWS BRIDGE** is of considerable scientific and technical value; as a pre-stressed concrete structure it is representative of innovative engineering technology and method developed in the 1950s, involving in its construction structural design, techniques and materials appropriate to a low-profile structure in a visually critical location with difficult foundation characteristics.
Criterion 3.1 & 3.3

SOCIAL VALUE

The **NARROWS BRIDGE** is significant through its continuous use as a traffic Bridge from the 1950s to the present day and is valued by the community for the close linkage of the City to adjoining residential suburbs such as South Perth and Applecross. It is important for its association with professional practitioners of high profile - the Consulting Engineers Maunsell & Partners and Consulting Architects, Sir William Holford & Partners, and as part of the initiative of the Stephenson/Hepburn Metropolitan Region Plan.
Criterion 4.1)

The Bridge is important in contributing to the community's sense of place, together with the associated Freeway System, to an understanding of the social, cultural and economic life of the City of the mid 20th Century and for its potential to promote community interest, cultural appreciation and tourism in the context of the Capital City of Western Australia.
Criterion 4.2

DEGREE OF SIGNIFICANCE

RARITY

The **NARROWS BRIDGE** is not rare as a prestressed concrete structure. It displays the characteristics of a specific engineering design method. The structure is relevant for its continuous use from 1959, notwithstanding the substantial changes which have occurred in traffic volumes during that time.
Criterion 5

REPRESENTATIVENESS

The **NARROWS BRIDGE** demonstrates the characteristic slim profile and structural form of pre-stressed concrete bridge design in the 1950s.
Criterion 6.1

The structure is tangible evidence of the development of the Metropolitan Region Scheme and the Traffic System which evolved as a result of that Scheme, and in this respect, the place is representative.
Criterion 6.2

CONDITION

The **NARROWS BRIDGE** is in a sound condition as a consequence of regular maintenance and upgrading of the main structural system by Main Roads Western Australia. There is present however, the evidence of superficial deterioration and inadequate regular, rigourous maintenance to the presentation of the Bridge.

INTEGRITY

The integrity of the Narrows Bridge is intact; the cultural value of the place has been maintained through its short history and its importance as an element in the landscape of the City is visually apparent.

AUTHENTICITY

The original structure survives with minor change; there is evidence of some deterioration. The Narrows Bridge has a high degree of authenticity.

3.2 STATEMENT OF CULTURAL HERITAGE SIGNIFICANCE

3.2.1 LEVELS OF SIGNIFICANCE

The following definitions apply to the grading of significance for heritage places:

- **Exceptional & Considerable Significance**

  Conservation of the place is highly desirable; the place warrants inclusion on any register of significance for National, State and local heritage value.

- **Some Significance**

  Conservation of the place is recommended; the place is of National, State and local heritage value and qualifies for entry into the *Register of Heritage Places* of the Heritage Council of WA, the *Register of the National Estate* of the Australian Heritage Commission, or the *Classified List* of the National Trust of Australia (WA).

- **Little Significance**

  The place is of interest only, at the level of local heritage value.

- **Intrusive**

  The place or elements of the place in its present form has a direct adverse effect on the character of the place. Elements of the buildings, usually introduced or modern elements, which are not culturally significant are noted as **"NOT SIGNIFICANT"**.

3.2.2 SIGNIFICANCE RATINGS

The assessment of cultural heritage significance for the **NARROWS BRIDGE** has determined the following levels of significance based on the criteria in Section 3.2.1 above:

Elements of Some Significance

- the piled foundations, pile caps and facing panels and pier columns
- the concrete structure of the Bridge and its pre-stressed structural system
- the concrete abutments
- the precast facing panels and aluminium balustrading
- granite faced pedestrian entry blocks and the Opening Plaque.
- elements which, although not original, have value in the current presentation of the Narrows Bridge and are of similar characteristics to the original:
  - the safety fences
  - aluminium lighting standards

3.2.3 STATEMENT OF CULTURAL HERITAGE SIGNIFICANCE

The **NARROWS BRIDGE** is of some cultural heritage significance for the following reasons:

- the place is aesthetically important through the resolution of its slim design and appropriateness as a traffic Bridge crossing the river at the western end of Perth Water immediately adjacent to the City of Perth
- the place is historically and socially important as evidence of the development of Perth in the 1950s, as an element of the Stephenson/Hepburn Metropolitan Region Scheme and of the traffic Freeway Systems developed to service the City and Metropolitan Regions since 1959
- the place is technically important as an early pre-stressed concrete bridge structure located across a narrow neck of the Swan River in Western Australia
- the place is a representative example of the standards, style and methods of construction for bridge structures in the mid 20th century; the Bridge set a standard for subsequent bridge design in the Perth region
- the place forms an important element in the landscape environment at the southern entry to the City and is a strong visual element which enlivens but does not compromise the view of the City from its southern approaches
- the place is relevant in contributing to a sense of place for the City of Perth.

3.3 AREAS FOR FURTHER RESEARCH

In order to provide a discreet and complete updated version of the description of the **Narrows Bridge**, the changes which have been carried out on its fabric since 1959, and changes in the perception of the cultural value and presentation of the structure, further research and archival recording should be carried out. The following areas are available to extract data relevant to the history and development of the Bridge.:

- the records of newspapers and Government files from the time of design and construction of the Bridge up to the present day
- oral histories of people associated with the Bridge during its lifetime.

3.4 CURTILAGE

(Refer to the drawings at pages 5a & 5b)

For the purpose of this assessment of cultural heritage significance, the curtilage of the Narrows Bridge (the area within which cultural values shall apply) shall extend 50 metres beyond the external sides of the Bridge, 50 metres beyond the face of the abutments at each end of the Bridge and to the bottom of the deepest Gambia pile supporting the Bridge structure, approx 40 metres below datum which is 600mm below normal river level.

CONSTRAINTS AND OPPORTUNITIES 4.0

4.0 CONSTRAINTS AND OPPORTUNITIES

4.1 INHERENT CONSTRAINTS

THE NARROWS BRIDGE has been determined by this conservation study to be a place of some cultural heritage significance. As a consequence, the place should be conserved and managed in a manner which maintains and enhances that significance.

This **Conservation Policy** will direct action to protect the special character of the place by influencing decisions to be made relating to the condition of the fabric and its use and to convey heritage value for the community in a tangible manner. The place should be conserved in accordance with this policy, presented for appropriate interpretation in its context and used in a manner consistent with its cultural and social values.

4.2 USER REQUIREMENTS

The owner Main Roads Western Australia intends that the place shall be conserved and continue in use. The intention is to retain the character of the existing fabric of the Bridge and to add additional lanes by widening the Bridge, necessary to address current transport needs and for user safety, but sensitively so as not to compromise the significance and cultural value of the present structure.

4.3 PHYSICAL CONDITION

The **Narrows Bridge** is in sound condition as a consequence of regular maintenance by Main Roads Western Australia. There is, however, evidence of wear and tear, a lack of maintenance to some of the Bridge elements, and superficial deterioration:

- an accumulation of dirt and storm water staining
- deterioration of the granite facings to the pedestrian entries of the footbridge
- graffiti
- water staining from reticulation
- leaching of water through concrete surface and the consequent build up of surface deposits
- erosion of dry stone paving to embankments exacerbated by pedestrian and bicycle movements
- uneven precast concrete paving
- unrepaired damage to safety barriers
- deterioration of paving and kerbing in the pedestrian area under the northern arch of the Bridge.

Attention to these issues is addressed in the Implementation Section (Section 6.2) of this

4.4 INTERPRETIVE REQUIREMENTS

The **Narrows Bridge** is an element of significance in the context of the City and the Freeway system which services the City. The Narrows Bridge is clearly and uncompromisingly interpreted as a river crossing - there are no specific requirements which need to be addressed to enhance an appreciation of this function.

4.5 STATUTORY AND OTHER REQUIREMENTS

Statutory and other requirements will be addressed in the context of the existing Narrows Bridge and as necessary in the consideration of additional lanes in a new, abutting structure.

Traffic regulations, public safety and the maintenance of aesthetic standards will be respected as a matter of course.

Issues which need to be addressed for both appropriate use and for protection of the physical qualities of the fabric as conservation constraints, are as follows:

- an improvement in safe and convenient pedestrian and cycle access and dual use of the footway section of the Bridge, and in the approaches to the footway at both extremities
- a maintenance of the aesthetic standards for any extensions or changes to the Bridge, to the same degree which applied to the existing structure
- attention to regular, programmed maintenance for all elements of the Bridge, including those elements in close contact with pedestrian and cycle use, as noted in Section 4.3 Physical Condition.

Security, health, safety and user satisfaction derive from proper conservation and need to be addressed as a critical part of the conservation policy and management of the place, to be enacted by observing statutory requirements but without compromising use or proper presentation. With the appropriate professional input and co-operation by the relevant authorities, primary requirements for retention and conservation can be achieved.

The Statutory Authorities and the Heritage Bodies should work with the owners in support of sensible conservation and change at the same time ensuring a viable future for the Bridge.

It is important to understand that the City is a living entity, subjected to continual change, and that its health and survival depends on the ability to accommodate change without compromising its social and historical integrity and without unreasonably imposing narrow statutory constraints derived from a purist and inappropriate determination of heritage values. As a service element to the City, the Narrows Bridge must also demonstrate an ability to accommodate appropriate change.

4.6 OPPORTUNITIES

The opportunity exists to address two issues which currently apply to the place. These issues underline the intention of the Conservation Plan, reinforce the elements of cultural heritage significance and facilitate conservation and change without compromising the value of the existing significant fabric:

(1) Conservation

This Conservation Plan has identified areas where restoration and maintenance works are required to be carried out to promote continuing use and to enhance the presentation of the fabric of the Bridge; the opportunity exists to proceed without delay to programme for these works and to enact them at the earliest appropriate time.

(2) Change

The opportunity exists to satisfy the need to extend the capacity of the Bridge, to improve safety for both vehicular and pedestrian/cycle use, and to improve the public transport system.

Change can be accommodated sensitively, for example, by increasing the width of the present Bridge provided the same external physical profile and visible materials are employed in the extension.

ATTACHMENT 3

Heritage Council Letter dated April 23 1999

Re permanent entry of Narrows Bridge on

Register of Heritage Places

51-453 v 3

Your ref:
Our ref: 4795
Enquires: Ms Christine Lewis 9220 4145

R. Moore

23 April 1999

CMR 6881

HERITAGE COUNCIL OF WESTERN AUSTRALIA

108 Adelaide Tce, East Perth, Western Australia 6004

P.O. Box 6201, East Perth, Western Australia 6892

Telephone: (08) 9221 4177
Freecall: 1800 644 177
Facsimile: (08) 9221 4151
heritage@hc.wa.gov.au

Chief Executive Officer
Department of Main Roads
PO Box 602
EAST PERTH WA 6892

RECEIVED
MAIN ROADS
29 APR 1999
COMMISSIONER'S
CORRESPONDENCE

Dear Sir

REGISTER OF HERITAGE PLACES

This letter is to advise you that the place known as *Narrows Bridge*, located at Perth & South Perth, has now been entered in the Register of Heritage Places on a permanent basis, pursuant to Section 51 of the *Heritage of Western Australia Act 1990.*

The Heritage Council is charged with the compilation of the Register of Heritage Places as the authoritative and comprehensive list of places throughout the State that are of sufficient significance to warrant special care.

A copy of the relevant Gazette notice is attached for your information, together with a copy of the Register citation.

Should you require further information, please contact Ms Christine Lewis at the Heritage Council offices.

Yours sincerely

Ian Baxter
DIRECTOR

Enc.

2. Interpretation

In this instrument—

"table" means the table in the Schedule to this instrument;

"the Act" means the *Health Act 1911* (WA);

"the Committee" means the Local Health Authorities Analytical Committee constituted under section 247A(1) of the Act;

3. Appointment of Members

Each of the persons named in column 1 of the table in the schedule are appointed as members of the Committee, pursuant to the provision of the Act specified in column 2 of the table adjacent to the name of that person, for a period of three years commencing on the date of appointment.

SCHEDULE

TABLE

Column 1 NAME	Column 2 SECTION
Mr Dominic Meyrick	(3)(b)
Mr Robert Boardman	(3)(b)
Councillor Kim Hicks	(3)(c)

Date: 22 March 1999.

JOHN DAY, Minister for Health.

HERITAGE COUNCIL

HR401*

Government of Western Australia

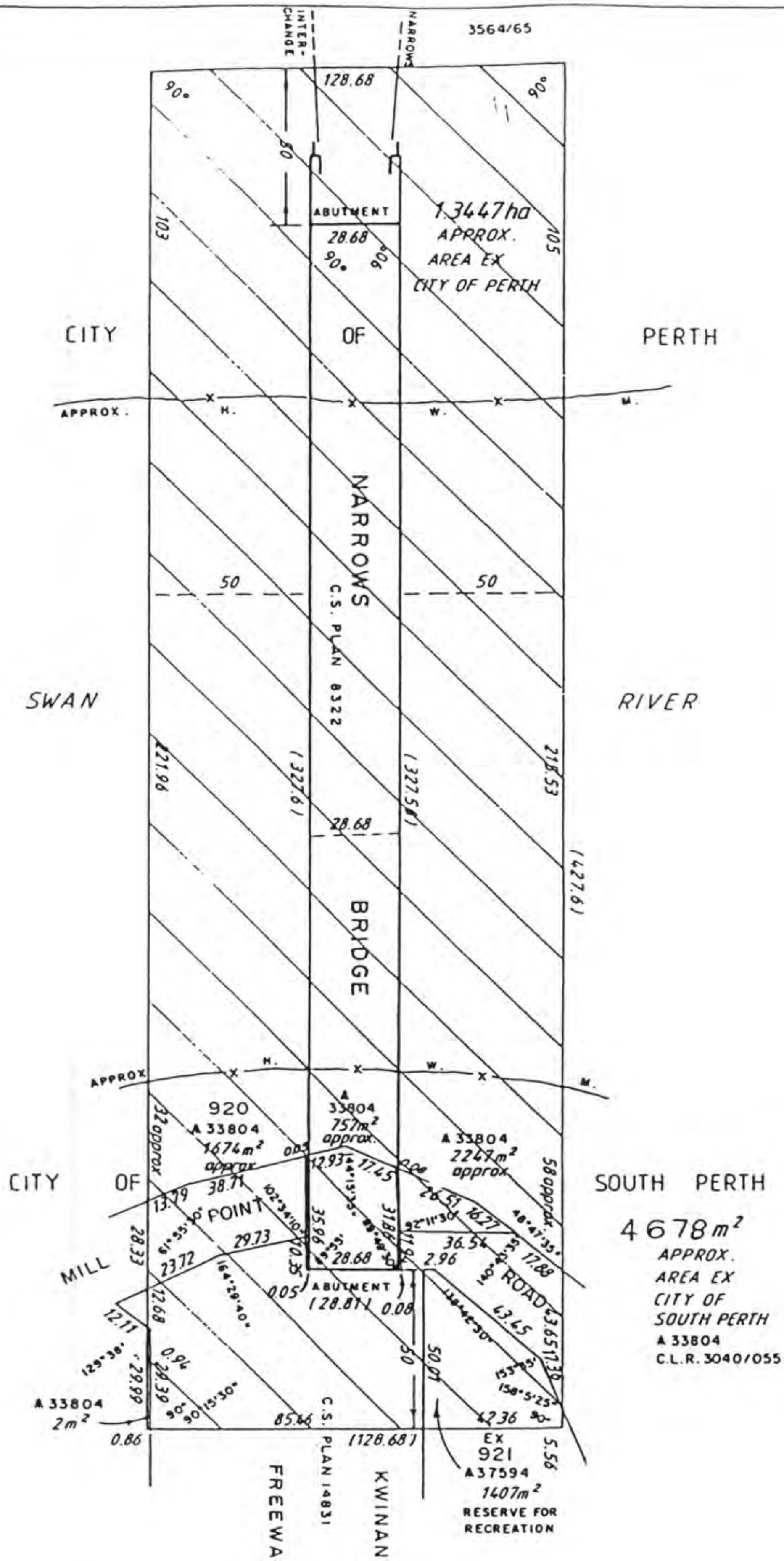
HERITAGE OF WESTERN AUSTRALIA ACT 1990

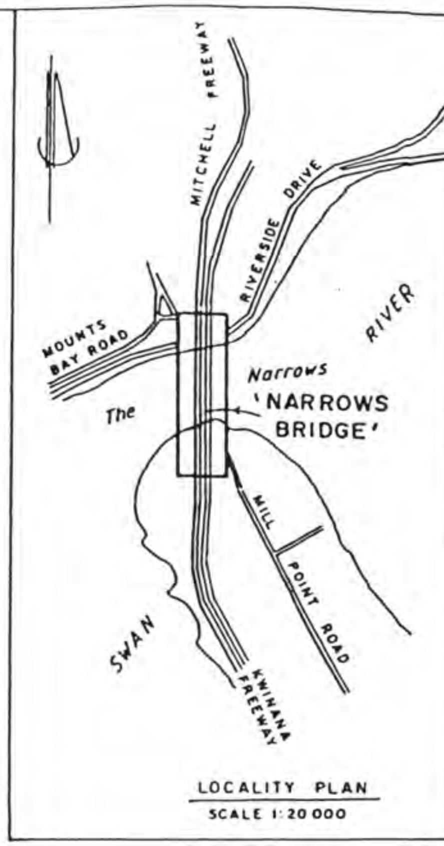
NOTICE OF ENTRY OF PLACES IN THE REGISTER OF HERITAGE PLACES

Notice is hereby given in accordance with Section 51(2) of the Heritage of Western Australia Act 1990 that, pursuant to directions from the Minister for Heritage, the places described in Schedule 1 have been entered in the Register of Heritage Places on a permanent basis with effect from today.

Schedule 1

Name	Location	Description of Place
Bruce Rock Shire Offices	Cnr Johnson & Bath Streets, Bruce Rock	Bruce Rock Lot 48, being part of Crown Reserve 15098 and being part of the land comprised in Crown Land Record Volume 3010 Folio 923.
Customs House (fmr)	Cnr of Phillimore & Cliff Streets, Fremantle	Fremantle Lot 2045, being Crown Reserve 40256 and being the whole of the land comprised in Crown Land Record Volume 3037 Folio 637.
Geraldton Customs Complex	7-9 Francis Street, Geraldton	Lots 20 and 21 on Diagram 95780, being the whole of the land comprised in Certificates of Title Volume 2140 Folios 670 and 671 respectively.
Millbrook Farm	Millbrook Road Yallingup	Those parts of Sussex Locations 461 and 474, being part of the land comprised in Certificates of Title Volume 1037 Folio 996 and Volume 1502 Folio 518 as together are defined in HCWA survey drawing No 0429 prepared by Steffanoni Ewing & Cruickshank Pty Ltd
Narrows Bridge	Perth and South Perth	Main Roads Western Australia Bridge No. 953 and those portions of: Main Roads Western Australia Road Reserve to the North and South of the said Bridge and The bed of the Swan River, being a part of the Port of Perth and Perth Lot 921, being part of Crown Reserve 37594 and being part of the land comprised in Crown Land Record Volume 3043 Folio 251 and Perth Lot 920, being part of Crown Reserve 33804 and being part of the land comprised in Crown Land Record Volume 3040 Folio 55, as together are defined in HCWA survey drawing No 4795 prepared by Steffanoni Ewing &





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REGISTER OF HERITAGE PLACES
Permanent Entry

1. **DATA BASE No.** 4795

2. **NAME** *Narrows Bridge* (1959)

3. **LOCATION** Perth and South Perth

4. **DESCRIPTION OF PLACE INCLUDED IN THIS ENTRY**
Main Roads Western Australia Bridge No. 953 and those portions of;

   Main Roads Western Australia Road Reserve to the North and South of the said Bridge and

   The bed of the Swan River, being a part of the Port of Perth and

   Perth Lot 921, being part of Crown Reserve 37594 and being part of the land comprised in Crown Land Record Volume 3043 Folio 251 and

   Perth Lot 920, being part of Crown Reserve 33804 and being part of the land comprised in Crown Land Record Volume 3040 Folio 55, as together are defined in Heritage Council of Western Australia survey drawing No. 4795 prepared by Steffanoni Ewing and Cruickshank Pty. Ltd.

5. **LOCAL GOVERNMENT AREA** City of Perth & City of South Perth

6. **OWNER**

Main Roads Western Australia	(Bridge 953 & Road Reserve)
Minister for Transport	(Port of Perth)
City of South Perth	(Reserves 33804 & 37594)

7. **HERITAGE LISTINGS**

• Register of Heritage Places:	Interim Entry	08/01/1999
• National Trust Classification:		----------------
• Town Planning Scheme:		----------------
• Municipal Inventory:		----------------
• Register of the National Estate:		----------------

8. **CONSERVATION ORDER**

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9. **HERITAGE AGREEMENT**

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10. **STATEMENT OF SIGNIFICANCE**
Narrows Bridge, a five span pre-stressed concrete bridge, has cultural heritage significance for the following reasons:

the place is a strong landmark element of the visual landscape which comprises the built form of the City and the *Narrows Bridge* and the natural form of the river and Mt Eliza,

this same visual resolution is apparent during the day and at night time in the context of an illuminated City and Bridge,

the place is the first physical manifestation of the Hepburn and Stephenson plan, which contributed to the development of the Freeway road systems in the State and the Perth Metropolitan Region Scheme from the 1950s,

the pre-stressed concrete structure is representative of innovative engineering technology and method developed in the 1950s. The construction involved structural design, techniques and materials appropriate to a low-profile structure in a visually, critical location with difficult foundation characteristics,

the place has associations with eminent consulting engineers, Maunsell & Partners in the U.K. and consulting architects, Sir William Holford and Partners in the U.K., as an element of the Stephenson-Hepburn Report of the 1950s which emphasised the need for aesthetic consideration to be incorporated into the design of the Bridge; and,

the place contributes to the community's sense of place as an element in the landscape of the City.

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REGISTER OF HERITAGE PLACES - ASSESSMENT DOCUMENTATION

11. ASSESSMENT OF CULTURAL HERITAGE SIGNIFICANCE

The criteria adopted by the Heritage Council in November 1996 have been used to determine the cultural heritage significance of the place.

11.1 AESTHETIC VALUE*

The slim profile of *Narrows Bridge* displays strong aesthetic characteristics. (Criterion 1.1)

The pre-stressed concrete form of the structure was an innovative bridge design in Western Australia in the 1950s. (Criterion 1.2)

The structure is a strong element of the visual landscape which comprises the built form of the City and the *Narrows Bridge* and the natural form of the river and Mt Eliza. The Bridge displays landmark values in the context of Perth Water and river beyond. (Criterion 1.3)

The same visual resolution is apparent during the day and at night time in the context of an illuminated City and Bridge. (Criterion 1.4)

11.2. HISTORIC VALUE

Narrows Bridge is important in the history of the development of the City of Perth. The Bridge is the first physical manifestation of the Hepburn and Stephenson plan, which contributed to the development of the Freeway road systems in the State and the Perth Metropolitan Region Scheme from the 1950s. (Criterion 2.1)

Built in 1959, *Narrows Bridge* is the realisation of plans, which were discussed from the 1840s, to bridge the narrow neck between Perth Water and Melville Water. (Criterion 2.2)

Narrows Bridge has associations with eminent consulting engineers, Maunsell & Partners in the U.K. and consulting architects, Sir William Holford and Partners in the U.K., as an element of the Stephenson-Hepburn Report of the 1950s. (Criterion 2.3)

The aesthetically pleasing design of the Bridge was emphasised by the consulting engineers, Maunsell & Partners and the consulting architects, Sir William Holford and Partners, to conform with the original brief and the advice of Professor Gordon Stephenson. (Criterion 2.4)

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* For consistency, all references to architectural style are taken from Apperly, Richard; Irving, Robert and Reynolds, Peter *A Pictorial Guide to Identifying Australian Architecture: Styles and Terms from 1788 to the Present*, Angus & Robertson, North Ryde, 1989.

11.3. SCIENTIFIC VALUE

Narrows Bridge is of considerable scientific and technical value. As a pre-stressed concrete structure, it is representative of innovative engineering technology and method developed in the 1950s. The construction involved structural design, techniques and materials appropriate to a low-profile structure in a visually, critical location with difficult foundation characteristics. (Criteria 3.1 & 3.3)

11.4. SOCIAL VALUE

Narrows Bridge is valued by the community as the main north-south access across Perth water, and for its continuous use as a traffic bridge from the 1950s to the present day. (Criterion 4.1)

Narrows Bridge contributes to the community's sense of place as an element in the landscape of the City. (Criterion 4.2)

12. DEGREE OF SIGNIFICANCE

12. 1. RARITY

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12. 2 REPRESENTATIVENESS

Narrows Bridge demonstrates the characteristic slim profile and structural form of pre-stressed concrete bridge design which developed in the 1950s. (Criterion 6.1)

Narrows Bridge is representative of the development of the Metropolitan Region Scheme and the Traffic System which evolved as a result of that Scheme. (Criterion 6.2)

12. 3 CONDITION

The *Narrows Bridge* is in sound condition as a consequence of regular maintenance and upgrading of the main structural system by Main Roads Western Australia. However, there is evidence of superficial deterioration.

12. 4 INTEGRITY

Being in continuous use since 1959, *Narrows Bridge* has a high degree of integrity.

12. 5 AUTHENTICITY

Narrows Bridge has a high degree of authenticity. Minor changes in the original structure reflect the changing needs of the Perth traffic system.

13. SUPPORTING EVIDENCE

Attached are key sections of the supporting evidence prepared by Ronald Bodycoat, Architect, 'Narrows Bridge Conservation Plan' (prepared for Main Roads, June 1998).

13. 1 DOCUMENTARY EVIDENCE

For a discussion of the documentary evidence refer to prepared by Ronald Bodycoat, Architect, 'Narrows Bridge Conservation Plan' (prepared for Main Roads, June 1998).

13. 2 PHYSICAL EVIDENCE

For a discussion of the physical evidence refer to prepared by Ronald Bodycoat, Architect, 'Narrows Bridge Conservation Plan' (prepared for Main Roads, June 1998).

13. 3 REFERENCES

Ronald Bodycoat, Architect, 'Narrows Bridge Conservation Plan' (prepared for Main Roads, June 1998).

13.4 FURTHER RESEARCH

Engineering reports are included in Ronald Bodycoat, Architect, 'Narrows Bridge Conservation Plan' (prepared for Main Roads, June 1998) as appendicies.

ATTACHMENT 5

Discussion on "The Narrows Bridge Perth, Western Australia".

Paper No.6498, Institution of Civil Engineers (October 1961)

The Author, in reply, thanked Mr Dennington and Mr Jenkins for their interesting contributions. As Mr Dennington rightly stated, the analysis was for an elastic homogeneous material of uniform thickness. In addition, the analysis was for small displacements and Poisson's ratio was neglected. The latter could readily have been included, but since its square was generally negligible when compared with unity, its influence was small. In any case, its value for reinforced concrete was doubtful and was apparently a function of the stress tensor.

58. The analysis was strictly valid only for uncracked shells. However, some tests had been performed on a hyperbolic paraboloid shell model of reinforced mortar and the results compared favourably with the corresponding solution of equation (67) of the Paper. The shell was supported on four parabolic generators by deep gables and the tests have been described elsewhere.[12]

59. Mr Dennington's suggestion that the concrete shell should be considered as a "sandwich" construction would appear to complicate the analysis rather than simplify it.

60. The Author agreed that some form of limit analysis was required, but saw no conflict between this and the linear analysis. More information was also required about the non-linear elasticity and stability of thin shells, but these subjects, like limit analysis, were relatively in their infancy. The few available test results should serve as useful checks on any proposed limit analysis, but it would be unwise to derive an empirical ultimate load formula from these results.

61. It should be noted that the "membrane" (or extensional) theory did not lead, in general, to an acceptable complete solution for shells of negative Gaussian curvature, since the relevant second-order partial differential equation was of the hyperbolic type and could not be solved for a closed boundary.

62. In reply to Mr Jenkins, if a condensed notation were not used, economy of symbols was even more important and, in addition, it was desirable to use a single symbol for similar functions. Thus, all stresses were denoted by σ, strains by ϵ, and extensional actions by n, to give only three examples. The suffix notation served to distinguish the various members of each group. In using this simple convention, the Author, like most modern authors, had abandoned Love's notation. Therefore, there seemed little point in illogically retaining Love's convention for displacements.

63. Whilst agreeing that the earlier part of the Paper could be summarized briefly as stated by Mr Jenkins, the Author felt that the condensation would have presented greater difficulty to the general reader than any departure from Love's notation.

64. In conclusion, there was one correction to be made to the Paper. The right-hand side of equation (90) should be "$-Et\nabla_r^2 G_y$". The minus sign had been omitted in reference (11) and the error had been repeated in the quotation from this reference.

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12 J. Munro and B. M. Ahuja, "An investigation of the strain distribution in reinforced concrete shallow thin shells of negative Gaussian curvature". Symposium on Shell Research. International Association of Shell Structures. Delft. 1961.

Paper No. 6498

The Narrows Bridge, Perth, Western Australia†

by

John Walter Baxter, B.Sc., M.I.C.E.

Edward Miles Birkett, B.Sc., A.M.I.C.E., A.M.I.E.(Aust.)

and

Edwin William Henry Gifford, B.Sc., M.I.C.E.

Discussion

Professor A. D. Ross (King's College, University of London) wished to comment very briefly on the relaxation tests on the strands, mentioned in § 37 of the Paper. These tests were first planned in 1956, at a time when strand was just beginning to appear in Britain; while at that time, considerable information was available about the creep and relaxation of individual wires, nobody knew what the loss of stress would be if one formed a bundle of those wires with a lay and then subjected it to tension; and so tests were obviously desirable, because it was thought possible that the relaxation might be distinctly more severe than in the case of an individual wire. There was no intention of embarking on a programme of research. What was wanted was a series of ad hoc tests simulating approximately the conditions which would obtain in the bridge and designed to indicate the order of magnitude of loss of stress.

109. With this limited objective in mind some special equipment had been developed which Professor Ross illustrated by slides. The primary element was a steel tube which not only carried the force in the strand tensioned within it but also fulfilled the additional function of a load dynamometer. By measuring the strain in the tube, the load in it at any time could be determined by comparison with a previous calibration. The strand was tensioned within the tube by hydraulic jacks and when the required force was attained, it was locked and held in its extended condition by chocks.

110. This equipment worked quite well but its accuracy was limited, and some modification would be desirable for more comprehensive tests. It did, however, meet the primary objective of getting an answer of the right order of magnitude at the earliest possible date without the delay required for the development of more elaborate equipment and techniques. The test did not in fact give the true relaxation under precisely constant strain since the tube expanded very slightly. However, the departure from constant strain was very small and the results had been corrected to take account of it.

111. He showed the results of eight tests from which it was seen that the relaxation after 2,000 hours ranged from 4 to 8% for strands in the as-drawn condition. The heat-treated specimens in some cases gave higher results. The variability in the results was due to differences in the time taken to tension which ranged from 15 to 25 minutes. The anchoring load varied from 23·3 to 25·4 tons, and some of the strands were over-stressed before they were finally anchored. All these factors tended to give variability in the relaxation but the order of magnitude under typical conditions was satisfactorily determined.

112. Although no doubt much information on the relaxation of strand had been accumulating since these investigations were commenced, Professor Ross thought that

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† Proc. Instn civ. Engrs, vol. 20, pp. 39–84 (Sept. 1961).

the results of a test on a typical strand extended to 4 years, i.e. 35,000 hours, would be of interest. The diagram showed that after 6 months the relaxation was about 7%, after 2 years 8% and no further increase had been detected in the third and fourth years.

Sir William Holford (President, Royal Institute of British Architects) said that the Authors of the Paper said more than once that the first requirement of the design was that the bridge should be of good appearance and worthy of its beautiful setting. As his partners and he were consulting architects for the project he wished to add a word about the collaboration required to produce that good appearance. It would be very brief; but, as Mr Baxter said, it would be a marked omission if it were not mentioned.

114. The first stage of collaboration in this case was over the setting, the connexions with the town plans of Perth and South Perth and the huge car park on the north of Perth Water, adjacent to the Central Area of the city—an unusual feature in itself. They made a landscape survey and a report on the north shore and Kings Park and the slopes of Mount Eliza. They contributed their views on the formal characteristics which the bridge might be designed to have. Unlike Sydney Harbour where the steel bridge structure is a monumental feature of the land and seascape, the setting at Perth favoured a structure subservient to the highway, which would have the appearance of a broad ribbon threading its way smoothly across the estuary with as little fuss as possible.

115. Lengths and proportions of spans were, as had been stated, selected mainly for appearance; and there again, as well as in the form of the columns and of the precast cladding to the deck structure they offered suggestions supported by models and drawings. It was an ideal method of working for an architect to know the fixed points and limitations imposed by the consulting engineers' design, but at the same time to be encouraged to put up for discussion even the most fundamental proposals for achieving formal interest, consistency and rhythm. They could not have been more fortunate in their relationships in that respect.

116. Once the principles of the design had been agreed the whole responsibility of course devolved on the consulting engineers; and he considered the detailed design of the unusually thin I-beam sections, which was the result of the search for efficiency and economy in their ratio of weight to strength, to be an outstanding example of that kind of expertise, *refining* the main design objectives and *accentuating* the formal quality of the bridge. So often the true slenderness or strength of a structure was counteracted by applied design which did not arise from a real identification of all the collaborators with those objectives.

117. Finally, they had the chance to prepare details for external details and street furniture, for the composition and texture of the precast panels, and their rather unusual alignment; for the double line of fencing on either side of the footwalks, with their massive handrails (as the bridge was also a grandstand during regattas); for the lighting standards; and for the planting which would eventually clothe the approaches and unite the north shore reclamation area with Kings Park.

118. He should like to end these brief remarks by saying that his partners (Mr Richard Gray and Mr Frank Stower) and he had regarded it as a privilege to be associated in this way on such a profoundly interesting job.

Mr K. H. Sørensen (Deputy Technical Director, Christiani & Nielsen A/S, Copenhagen) said that his company had had the privilege of building the Narrows Bridge, for which he felt great credit was due both to the designers and to the Western Australian government, which had put the aesthetic demands before the economic.

120. The construction time specified in the contract was 2 years, and for a bridge of this magnitude time therefore became the essence of the contract, all the more because at the time his firm were not established in Australia. They were, however, fortunate in securing the co-operation of a good local firm. This had enabled a quick start to be made on all the preliminary work.

121. As would have been seen from the film, quite a lot of the plant was specially designed and purpose-built for the job, and in this connexion they had experienced quite a headache in regard to delivery time and supply. He fully agreed with Mr Baxter that it would certainly have been better if they had been able to use a winch of sufficient capacity to avoid a return block in the pile driving, and such a winch had been ordered, but unfortunately it completely failed to do the job.

122. One of the principal reasons for their decision to present an alternative proposal for the execution of the work was their fear that the use of one single major piece of plant, such as the large floating crane visualized in the consultants' proposal, would make the job too dovetailed and involve a major risk of serious disorganization of the work in case of difficulties with this piece of plant. By the use of a staging they were able to obtain ready access to all the various working places and achieved a considerable independence of the various operations. This became a factor of major importance when they encountered the various snags mentioned in the Paper.

123. The first of these were the difficulties with the casing of the Gambia pile, which proved rather weaker than what both the consultants and they themselves had anticipated. It became necessary to drive with great caution, and this naturally tended to slow up the work. The driving of piles of great length would naturally always involve a number of problems, both of a practical and a more theoretical nature and the difficulties encountered could, therefore, possibly not be considered as serious reflexions on the Gambia piles. They had felt that the piles were driven rather deeper than was strictly necessary.

124. A more serious consideration was the cost of the Gambia pile, which worked out at about £A2,000 on an average, corresponding to something like £14 per ft. The decision to use the Gambia pile must have been taken about 6 years ago, and in the meantime the use of prestressed concrete for long piles had taken considerable steps forward. He felt that today the choice would probably have been a hollow, cylindrical, prestressed pile, the cost of which probably would have been considerably below that of the Gambia pile.

125. Mr Baxter mentioned in his Paper that there was ample room for working sites and this was also correct as originally planned; but, due to the delays in the piling operations, and particularly the difficulties encountered in the lack of stability at the northern embankment, they had found at one stage that the casting of beam elements was going too well compared with the rest of the work. They had naturally been most anxious to keep this section of the work going, and therefore were forced to look round for more space in which to store the precast beam elements. The casting yard was accordingly extended by the reclamation of a further piece of land, and it was decided to use the staging as a sort of storage area, or storage platform.

126. The original plan had been to erect the beams in pairs and to stress them as soon as the one pair had been completed, which meant that the staging would never be loaded with much more than the weight of two beams. However, when they started using the staging as a storage platform they were not able to stress the elements as the piers were not completed, and they therefore actually loaded the staging with eight beams, unstressed. This had not particularly worried them at the start because the test-loading of the piles had shown that they should be able to take the load, but it had given rise later to very considerable worries because the whole thing had probably become rather top-heavy, and horizontal movements of the staging took place, which made it necessary for them in many instances to correct the position of the elements before they could be joined. At the northern end the problem became particularly serious due to the unstable bottom conditions mentioned by Mr Baxter in the Paper. They had not, therefore, been particularly happy about the consultants' solution to the permanent piles at the north shore pier, because it involved a preloading of the area which they feared might result in a slide, which could have serious consequences for the staging. They would have preferred to go the opposite way and to create stability by removing weight in the area. This would, of course, have entailed the support of the road between the north shore pier and the northern abutment on a slab supported by piles, but the special pile arrangement in the north shore pier could then have been spared.

127. They had endeavoured to secure the stability of the staging by pressing down raker piles, and had further tied the staging by heavy cables to the completed piers. One night, however, the bolts by which the cables were fixed to the pier broke and the whole northern end of the staging, which at the time carried all the beam elements, moved several inches out of position. They had experienced a very worrying time but fortunately were able to expedite the stressing and overcome the difficulties without any real upset.

128. With regard to the prestressing operations, it would have been appreciated from the Paper that certain difficulties were encountered, particularly with the anchorages. When one read that the total number of failures numbered only about 0·5% it might not sound so very much, but it certainly gave rise to a lot of worry on the site, and it was difficult not to reflect on the over-all safety factor particularly, because there was danger involved in the failure of an anchorage. Probably a good deal of their worries were unfounded; at least, all the various operations were completed without any serious mishaps. As a special precaution they had generally grouted the strands in the anchor blocks almost immediately after the stressing was completed, and this apparently fully secured the cable.

129. It was mentioned in the Paper that the stressing force on each stand was about 26½ tons, which corresponded to about 83% of the 32 tons' strength specified for the cables in the contract, but in his opinion this did not give quite a correct picture because when measuring the strength of the strands at the factory they were not secured in the stressing machine by a wedge anchorage of the type used at the Narrows Bridge, which really reduced the strength of the strand by at least 5 and possibly in some cases even by 10%. This really meant that during the stressing they had come up to something like 90% of the specified ultimate strength of the cable, which in their opinion was too much. The fact that the strands supplied by the factory really had a strength of approximately 10% above that specified probably became a very important factor.

130. Economy was, of course, a very important thing, but in the over-all cost it did really not help one much to go to the extremes in the working stresses, especially if it involved difficulty in the execution. He felt that not only when it was a question of cables outside the beams but also when one used inside cables, it would be a good thing to provide for a few extra cables just for an emergency; if the circumstances on the site made it necessary one could stress them or leave them out, as desired.

Mr A. J. Harris (Partner, A. J. and J. D. Harris) said that a bridge of this nature had almost nothing but its line visible. There was the hand railing and the precast concrete panelling down the side but basically it was two lines, a top line and a bottom line. Neither of these lines was ever seen—or hardly ever seen—in pure elevation; indeed, due to the tapering of the bottom boom they were curves in three dimensions: Now in this bridge there was a certain discord between the curve of the soffit in elevation and the tapering of the boom in the plan. As soon as one looked at the bridge from an angle one saw a slightly unfair curve.

132. The second point related to the actual profile of the soffit of the bridge. A sudden change in direction of a line is obvious and can be ugly; a sudden change in curvature is less obvious and, almost for that very reason, is nearly always ugly. Now transition curves bridged a change of direction with a continuous change of curvature; there were the logarithmic and other spirals available, all of them curves which, according to the folklore of engineering were found in nature (as in sea shells) and in art (notably in furniture of the better periods). In this particular case his criticism was that the shorter approach spans appeared to have a continuously curved soffit and one then came to the centre span where the curve appeared to run into a length of straight line in the middle.

133. When one saw this bridge as nine people out of ten saw it—extremely foreshortened—these continuous curves followed by a curve with an apparent straight portion in the middle was a feature which he at any rate found disturbing; all views, of course, being a matter of taste, and this being merely his own view.

134. Lastly, in connexion with the precast concrete panelling, he had to admit that personally he regarded this as a mistake. The bridge would have been a very fine looking one with those exposed cables visible, and he felt personally that the twist in the surface of the panels was a quotation from another bridge entirely, and a quotation out of context at that.

Mr T. G. Bingham (Resident Engineer, Hammersmith Flyover; G. Maunsell and Partners) noted that the Authors had described the bridge in considerable detail in their Paper, and Mr Sørensen had made some very pertinent remarks on the construction problems and the manner in which they were tackled. He wished to say something about the first of the three problems tackled while in Perth—the driving of the Gambia piles.

136. Difficulties were encountered with the very first pile, and it was some little time before they really got into their swing and got the job going at a good speed. During that time there was some pessimism as to the success of the pile. This was eventually overcome and the later driving and the finished product were to everybody's satisfaction. But, as Mr Sørensen had pointed out, the cost proved rather high, and he had suggested that, today, other types of pile would be preferred to the Gambia. He would not argue with Mr Sørensen on the choice of other types of pile; there were new types being developed all the time, and prestressed concrete was naturally making a big bid, but he felt that, on the evidence of this one job at Perth, the Gambia pile was being given rather an unfair treatment. It was the first time the piles had been used in this manner, and both the contractors and the engineers were to some extent feeling their way as to the best method of driving them. As Mr Sørensen had admitted, they were rather unlucky with the piling winch brought out to Perth and had to operate throughout the contract with other winches which they obtained at short notice, and which were not the ideal ones that they would have chosen had circumstances been different. He suggested that, due to these rather unfortunate circumstances which arose rather rapidly, pile driving was not as efficient from a cost point of view as it possibly could have been if a similar job had to be done again with their present experience and a new approach to the plant problem.

137. Looking through the records of pile driving he had observed that when the piling plant was in operation the piling hammer itself was working for less than 30% of the time. Moving between piles and pitching piles took a little less than a third of the time; driving them just under a third; and quite appreciably more than a third of the time was spent in welding on additional lengths, which was a necessary operation, and in delays, stoppages, etc. It had seemed to him that much more economic driving could have been obtained if the plant had been so arranged that pairs of piles could have been driven in tandem, one being driven while another was being extended. In general the piles were driven in three lengths, pitched in one length and twice extended, and the extension times were sufficient very often for another length to have been driven while the welder was at work. The plant unfortunately had not permitted this to be done. They had attempted to move the piling frame over to another pile while one was being welded, but the equipment was not designed to do that, and it did not prove economic in the circumstances. He felt that with a new plant, and with these problems in mind, more efficient driving could have been obtained.

138. Mention had also been made of the careful driving of piles due to the delicacy of the casing. This was a matter which was studied at some length, during the contract, and special tests were arranged, as mentioned in the Paper, with the University of Western Australia. These appeared to establish, within the limitations of the tests that were carried out, that the failures and breakages were mainly due to bending stresses in the pile added to the normal driving stresses. It was also apparently established in the tests that substantial additional stresses could be caused when the upper length of the pile was held in sands overlying the soft mud of the river bed. In almost every case where breakages occurred in welds, bending was present to a considerable degree. This perhaps was borne out to some extent by the fact that, in a number of

cases where breakages occurred in the welds, it was found that particularly heavy driving of adjacent piles was necessary at the time when they were passing the depth at which the neighbouring pile had failed. This seemed to suggest that lenses of hard material were being met and that, whereas in one case the piles had been driven through the lens, in another the pile may have struck the edge of the lens and been deflected by it.

139. It was perhaps significant that the special piles which were driven off the north shore pier with the swaged out casings were driven without any failures. They had been most nervous, when the first of these had been driven, as to how they would go down, because it was felt that the swaged out upper part of the casing would hold the pile up, and that the toe might attempt to go on driving, leaving the upper swaged out portion behind. As many jets as possible had been put round the pile, but even so it was quite remarkable that, hitting those piles harder than any of the normal piles in the job had been hit, there were no breakages; and although the diameter of the pile increased from 31 in. at the bottom to 43 in. at the top, they had managed to pull down through the ground that additional 12 in. of diameter, hitting the pile from below the point where it was swaged out. That did suggest that really the friction on the casing probably was not the major cause of pile breakages, and that bending was the much more likely cause, in the slender, normal pile.

140. Some quite interesting test measurements had been made during the driving, using various drops of the hammer according to the ground conditions through which the pile was going. When the driving was hard a 4 ft drop of the 10 or 12 ton hammer was normally used. When the nose was in mud and perhaps the upper part of the casing was held by the surface sands, a small 1 ft or 2 ft drop was used, easing the pile through until the nose met some resistance to take the blow. The set of the pile under various drops of the hammer was measured, and on changing the drop the change of set was particularly noted. The speed of operation of the hammer for the different sizes of drop was also recorded, and it was found, not surprisingly, that with the smaller drops, although much less energy was put into the pile per blow, the speed of hitting the pile was very much greater, and a very much larger number of 2 ft drops, compared with the corresponding number of 4 ft drops, could be achieved in a given time. Taking into account both these factors, the efficiency of the set that could be obtained with the different sizes of drop and the speed of operation of the hammer, it was found, with the particular type of plant used at Perth and not necessarily applying anywhere else, and taking the 4 ft drop of the 10 ton hammer as the normal, 3 ft drops were 73% efficient and 1 ft drops 41% efficient. It was quite surprising that with 1 ft drops of the hammer very nearly half as much energy was being put into the pile as with the 4 ft drops.

141. There were other problems such as breakages of strands, but at Perth the failures were mostly at the beginning of the contract, and later on the operations went much more successfully and finished quite successfully.

Mr G. Marsh (Bridge Engineer, Main Roads Department, Western Australia) stated that Mr Harris was quite right in his remark about the local attitude towards the bridge. The people in Western Australia were very pleased with it. In spite of Mr Harris's remarks, aesthetically the bridge did everything asked of it, and it was felt that it compared very favourably with any other bridge of its type in the world.

143. With regard to the protective cover to the cables and the behaviour of the bridge since it had been put into service, as would have been noted from the Paper, special measures had been taken to protect the prestress cables after shrinkage cracking had occurred in the protective concrete covering. Such cracking, he believed, could be entirely avoided by attention to various factors. If fine dry concrete, rather than a grout, was vibrated in, this would help. A gap could be left between groups of three columns of cables in section, so that a 1 in. poker could be inserted. It would not add significantly to the weight of the structure and would allow the covering concrete to be protected. Prestressing of the main members should be carried out as soon as possible after casting, so that a larger shrinkage and creep loss would be available to offset the shrinkage of the protective cover. In addition the protective concrete should be placed

as soon as it was possible to do so after stressing—again so that as much of the shrinkage and creep losses as occurred in the main members would be available to offset the shrinkage in the protective covering.

144. He had noted that there was no visible cracking of the protective concrete to the external cables of three bridges near Ghent in Belgium.

145. Perhaps the Authors could say whether cracking had occurred in the protective covering to the external cables of Hammersmith Flyover.

146. Returning to the Narrows Bridge, he had just received some information about its recent behaviour. Settlements had been recorded since April 1960, both by his department and by the consultants. There was apparently no settlement up to the time the consultants ceased taking measurements and since then no appreciable settlements had occurred.

147. Temperature movements had also been taken, and he had roughly analyzed the correlation of temperature movements of the bridge with temperatures taken at the Perth Observatory ¾ mile away, during the past 12 months. The movements were recorded three times on one day in each month, so that the maximum range of movement had probably been missed. The recordings showed that a creep and shrinkage shortening of the bridge (1,100 ft) of ½ in. had occurred in the last 12 months, almost all of it during the summer months. Making allowances for this, it was rather interesting to note that the coefficient of temperature expansion came out between 0·000006 and 0·000007 per degree F. The mean daily movement seemed to correspond to the mean daily temperature, with a slight dependence on the previous day's mean temperature. It seemed as though temperatures older than one day had no bearing on the movement of the bridge. Insufficient readings were taken to determine how the maximum daily movements correlated with temperature. No very hot days were included.

148. Earth movements (mentioned in § 60) continued at the North Shore pier, and since the measurements referred to in the Paper further movements of $1\frac{1}{16}$ in. vertically and ¾ in. horizontally had occurred, with no relative movement between the North Shore pier itself and the other piers.

The following contributions were received in writing:

Mr G. M. Cornfield (Senior Engineer, The British Steel Piling Co. Ltd) wrote if the Authors could please give some information on the method of filling the piles with concrete after they had been driven to their final set? It was assumed that the concrete was simply dropped down each of the tubes after the reinforcement had been placed in position, but was any vibration of the concrete carried out and if so by what means? In § 104 details were given of the concrete mix used for the filling of the pile—was this mix used throughout the length of each pile or alternatively was the cement content increased for the filling of the lower part of each pile? It would also be interesting to know whether any variation in the filling procedure was made in respect of the raking piles as compared with the vertical ones, and also whether any tests were carried out to check on the properties of the concrete in the lower part of the piles at this site.

Mr N. B. Hobbs (Geotechnical Consultant, Sir Bruce White, Wolfe Barry & Partners) observed that he could not see the need for such an elaborate and no doubt costly anvil contrivance at the lower end of the steel tube pile. In his opinion a load of concrete, replaced when necessary would have served just as well, and he felt that the Authors in using such a pile must have had some sound reason not disclosed in their Paper. Perhaps they would be good enough to go into further detail in this matter.

Mr Ove Arup (Consulting Engineer, Ove Arup & Partners) wrote that the paper mentioned that the first layout of the roads on either side of the Narrows Bridge necessitated a skew bridge, and that this undesirable feature, which would have led to great complexity of design and construction, had been avoided by a minor re-alignment. This

difficulty had been overcome in a sketch design prepared by his firm for this bridge in 1955 before the present Consulting Engineers were appointed (Fig. 39).

152. Mr Arup's firm had accepted the skew line, forming an angle of about 30° with the current, for the simple reason that the data supplied to them did not enable them to evaluate the possibility of altering the road lay-out. The question of one long span was discussed, but this would have meant an overhead structure (suspension bridge) which was considered undesirable from a landscape point of view. The best that could be done with a low structure leaving the view unobstructed was three spans with two middle piers. However, for reasons of economy it was thought best to avoid staging in the channel by adopting a construction which could be cantilevered out from the two middle piers. This could be much better achieved by replacing each centre pier with two narrow piers about 100 ft apart; these twin piers would form a natural harbour for supplies by barge and would, when connected, form a stable base from which to cantilever in both directions. They arrived then at a system with two double piers which, with their cantilevers, accounted for 317 ft of bridge each, and three floating spans, one of 165 ft and two of 145 ft, connecting the piers with each other and with the shore.

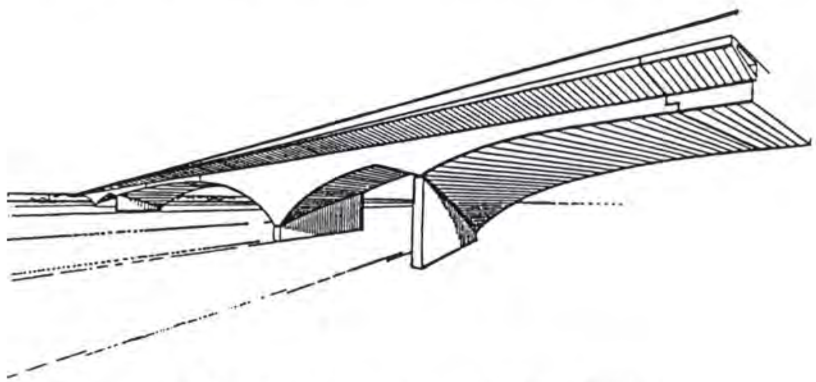

FIG. 39.—SKETCH DESIGN FOR THE PROPOSED BRIDGE

153. Then they had to deal with the problem of skewness. The narrow piers, consisting of one row of large piles protected by a pile cap, would have had to follow the direction of the channel and the current. If they, in order to preserve the symmetry and the logic of the system, were to cut the floating spans on the skew as well, the loads would have tended to concentrate round the outer ends of the twin piers and they would have had all the usual complications resulting from skewness.

154. To avoid this, they cut the three floating spans square to the line of the bridge as in Fig. 40. The bridge was perfectly normal between the lines A and C, F and J, and M and O. Only the regions around the twin-piers from C to F and J to M presented unusual features. The cantilevered portions of the bridge formed a trapezium—for instance between the lines B_1–B_2 and C_2–D_1—with a short cantilever springing from C_2 and on the other side of the bridge a long one springing from D_1. The long cantilever B_1D_1 was identical with the short one up to line C, then it continued along the natural curve of the cantilever down to D_1. Between two single piers the soffit dipped down at points D_1 and E_2, and at the points C_2 and F_1 it met the piers higher up.

155. This arrangement solved the problems of skewness. Admittedly there was a small deflexion at point C_1 which did not occur at C_2, but the stiffness of the large cantilever between C_1 and D_1 was such as to make it insignificant.

156. The interesting thing, however, was the rather unusual shape of the bridge which resulted logically from these purely practical and structural considerations.

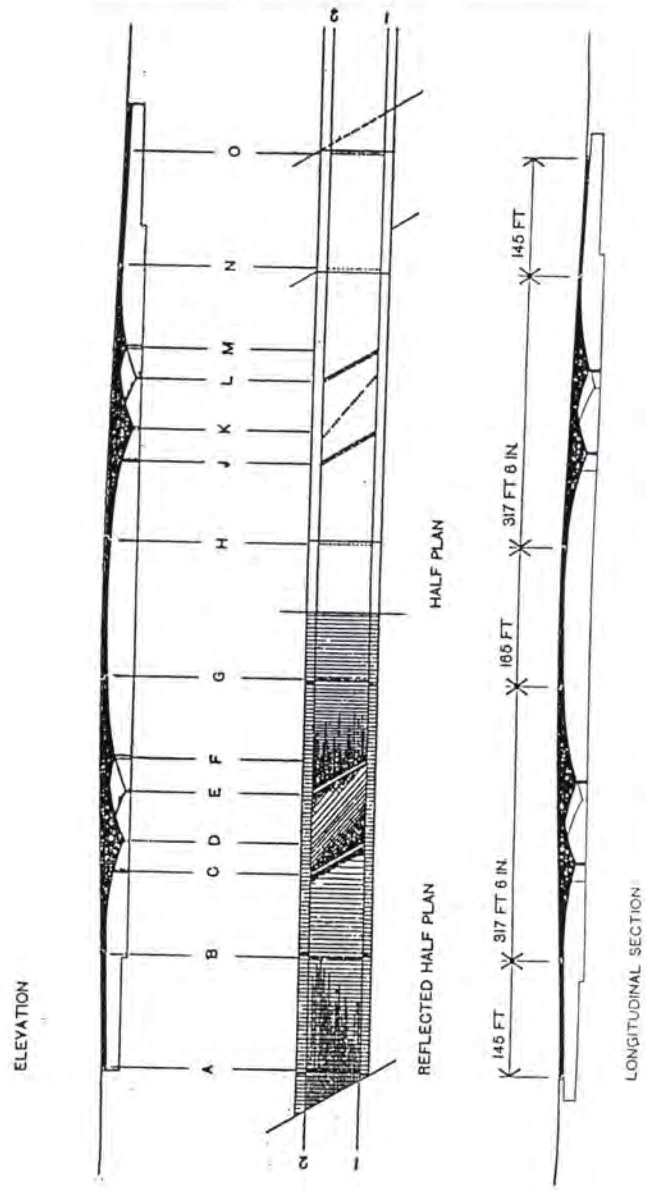

FIG. 40.—PROPOSED DESIGN FOR NARROWS BRIDGE

Mr C. H. Partridge (Braithwaite & Co. Engineers Limited) wrote to ask referring to § 67 if the authors would please state whether they had had second thoughts on the fine tolerances specified for the precast units?

158. No doubt the authors were influenced by considerations of appearance and weight saving in specifying the very close limits of $\pm\frac{1}{8}$ in. If the formwork manufacturer was given $\pm\frac{1}{32}$ in. and the same amount was allowed for deflexion, then $\pm\frac{1}{16}$ in. was left for setting up. In a welded steel form welding distortion alone might swallow the tolerance. To cut deflexion down to $\pm\frac{1}{32}$ in. required a heavy and correspondingly expensive form. Setting up to $\pm\frac{1}{16}$ in. was no doubt practicable but was costly in time and labour.

159. It would seem quite unnecessary to specify very close limits on the lengths of individual segments providing that the finished beam was within the specification. Again it should be possible to specify both maximum and mean tolerances for dimensions of webs and flanges. The contractor would then be assured that small local errors would not cause a unit to be rejected.

160. What was a contractor to do when faced with a very tight specification? If he honestly tried to abide by it he must put in prices to suit, and he must allow for an increased number of rejected units. Alternatively he could assume that after a few rejections the R.E. would concede that the specification was impracticable. This was not a satisfactory basis on which to prepare a tender. It put at a disadvantage the reputable firm which tried honestly to turn out the work as specified. Moreover if wider tolerances were in fact feasible and could be written into the specification it was at least possible that the client would benefit financially.

Mr J. W. Baxter in reply said that he wished to express his thanks for the appreciative remarks made by various contributors to the discussion.

162. Referring to the questions put by Mr Sørensen he would suggest that the choice of pile in any particular case was not simply a question of a cost per ft but must take account of other factors. A friction pile to be driven to a level did not need to be cut off and a prestressed concrete shell pile was suitable and economical in such circumstances.

163. Where piles were driven to a small set or refusal and the final level was not controllable cutting off excess length was necessary and in these cases a steel shell scored as the cutting neither damaged the pile nor yielded material which had to be discarded.

164. If a layer of very hard material had to be penetrated on the way down, it was very reassuring to use a type of pile like the Gambia pile in which the unit which had to be driven was in fact "temporary works" and the structural unit, namely the reinforced concrete core, was never subjected to driving conditions and could therefore be known to be unshattered.

165. A futher point which affected economics was that some types of prestressed concrete piles were covered by patents which involved royalties or the employment of a licensee.

166. In the conditions met at the Narrows with hard driving and unpredictable off-cuts the authors' choice today would be the same as before.

167. Mr. Sørensen expressed the view that the "north shore problem" could have been dealt with more cheaply by removing material and building the riverside road in suspended construction. A serious objection to this solution lay in the possibility that in the distant future someone might replace the material having forgotten the reason for its original removal or the probability that the river itself would effect replacement perhaps in the near future. With these considerations in mind the policy of loading the bank more heavily during construction than it could be expected to be loaded in service was thought to be a safe one and the authors continued to hold that view.

168. Admittedly the solution adopted would have been more expensive than it in fact was had a major slip been caused by the loads added to induce compression and prove stability but, even so, the authors doubted whether the cost would have been greater than that of the alternative solution as the cost of suspending the riverside road would have been severe.

169. Referring to Mr Marsh's question regarding cable protection concrete at

Hammersmith Flyover slight cracking had occurred, but not of such a significance as to raise doubts regarding corrosion of cables or to necessitate further protection.

170. The settlement figures given by Mr Marsh were interesting in that they generally confirmed that nature was behaving initially in much the same way predicted by Dr R. E. Gibson (Lecturer at Imperial College) who gave advice on the soils aspect of the problem. The Authors wished to apologise for the omission from the Paper of their thanks to Dr Gibson for his valuable assistance.

171. Replying to Mr Cornfield the concreting of the piles was carried out initially using a bottom opening skip which was dropped the last three ft on to concrete already placed in order to consolidate that concrete and also to operate the opening mechanism. This method was retained for raking piles but filling of vertical piles through an "elephant's trunk" about 15 ft long was permitted in order to save time. The top 30 ft length of the pile was vibrated by means of poker vibrators. Some enrichment of the mix was adopted for concrete not placed by skip. The only check made on the placing was a volume check which showed a very good degree of compaction.

172. The Authors would not agree with Mr Hobbs that the anvil details were unnecessarily complex. The driving was hard and a means of transmitting the forces to the pile toe without relying upon bond between the concrete and the shell near the point of impact was necessary. Adopting a driving plug of concrete as he suggested would have been objectionable for two reasons. Any removal and replacement during driving would have involved expensive delays compared with which the cost of the anvils themselves would not have been significant. Secondly the removal of the plug would have been required to achieve the continuous reinforced concrete pile core which was desired and this would have proved a difficult operation in the 31-in. dia. working space available. In fact, although men were willing to work down the piles, it was doubtful whether such working conditions could have been imposed contractually and one object of the design was to avoid the need for them.

Mr E. W. H. Gifford in reply said that he would deal first with the question of appearance, as it concerned both Sir William Holford's contribution and that of Mr Harris. Sir William had paid the designers a compliment when Mr. Gifford took the first set of drawings along for discussion. Sir William had said that the best thing he could do with the design was to leave it alone, so that in a sense if there was any fault, as suggested by Mr Harris, it was not Sir William's. He did not agree with Mr Harris's point about the number of people seeing the bridge from other than the full elevation. From the city of Perth the bridge was seen at a distance in part elevation, and could be thus seen by most of the citizens a great deal of the time; whether they looked at it was another matter, but theoretically one could look out from Perth and see the bridge all day long. On the foreshortened view, which could be seen as one went round underneath at 80 miles an hour, one could see the distortion mentioned by Mr Harris, and there were two or three problems about this which were worth mentioning. First of all, there were very few five-span bridges of variable span. Waterloo Bridge, for instance, has five equal spans. The span proportions chosen for Narrows were unusual but did give a pleasant appearance. The problem then facing the designer was that of relating the parapet curve, the soffit curves and the springing angles at the piers (Fig. 41, Sketch 1).

174. After examining a large number of bridges he had concluded that unless the springing angles at each pier were symmetrical about a line normal to the parapet, the bridge appeared either to tilt forward or to tilt backwards (Fig. 41, Sketch 2).

175. Many bridges, particularly those with three spans appeared to give this effect, and so the designers had set themselves the task of getting these angles right as this seemed to be important. This resulted in conditions which gave a more succulent curve in the intermediate span (spans B and D in Sketch 1) than in the end and central spans, which meant that in the foreshortened view one had hummocks at B and D with the long span C appearing flatter between them. This was the real problem.

176. The central span itself posed another problem. The required navigation clearance, in conjunction with the springing angle, had forced a curve which was near to

a cubic parabola, whereas spans B and D were near to square parabolas. The central span was a fair curve on the drawing board but it was very flat across its middle part. The point where the curve lost its pitch was the point of temporary suspension, so that a further difficulty was not only the flatness but the fact that it was extremely difficult to get the levels of a bridge of this kind precisely correct. It must be realized that the theoretical deflexion downwards of the bridge was 25 in. under dead load and by prestress 27 in. upwards; so that to get it in the right place there was a very small difference of very large numbers, and in fact at one time one cantilever was 7 in. higher than the other when they were loaded with the centre span, and anybody seeing that span at that time would have been very worried. He had seen it and was certainly worried!

177. This point was now within 2 in. of its correct position and the one on the other side was exactly right. This favourable condition had resulted from the high proportion of creep recovery obtained from the high strength concrete. Nevertheless there was a slight discontinuity at that point, and because of the very sensitive curve this was noticeable to the observant eye even on a span of that order. This is a very difficult problem in the construction of concrete bridges with long spans. One could make small scale models but they could not be made accurately enough to show up this type of thing. The only solution was for a client to have two bridges, and the second one would be better than the first!

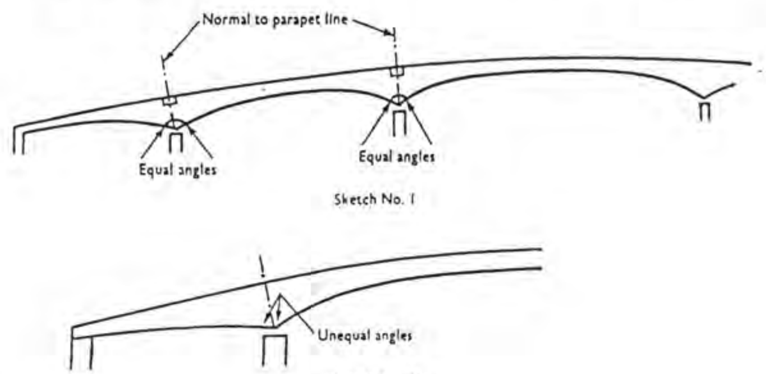

Fig. 41

178. Professor Ross had mentioned the five year period of relaxation and he thought this was very encouraging, because the curve was now flattened off in a satisfactory manner. There had been much discussion in the past about logarithmic extrapolations and so on, and it seemed that the curve for an early part of its life was logarithmic, so that mathematicians would say that it must continue to be logarithmic, but fortunately it was not, because presumably the steel did not know about it! The curve flattened off and stayed that way and the value of loss taken, 10%, was shown to be the realistic and safe one. With further experience this figure would probably be reduced.

179. Mr Sørensen's contributions were very interesting and he entirely agreed with him on a number of points, particularly that his alternative method of construction gave him independence of various operations. Indeed it had, so much so that the designers were faced with the problem of having worked out a sequence of operations which they thought would be followed but in the event a very different sequence of operations occurred, which was entirely reasonable from the contractor's point of view, but set a number of problems in calculation for temporary conditions which had not been anticipated. He could only say now that in the future he would be a lot more careful about changes in erection method and would try to specify rather more carefully the various

orders in which things should be built, because he had found that some things were being built "backwards", which could be rather difficult!

180. He also agreed with Mr Sørensen that it was unwise to try to get too much out of the prestressing steel. This was a disease which seemed to strike one when designing in prestressed concrete rather more than when designing in steel or reinforced concrete; but the points made did require a little explanation. Mr Sørensen had mentioned an insufficient factor of safety on stressing. This was dependent on the degree of reliability of the anchorage. In the event the degree of reliability obtained at Narrows, because of metallurgical troubles with the barrels, was not as high as had been expected, but when the anchorages performed as they normally would do and subsequently had done, then the factor of safety was perfectly adequate.

181. He had to confess to having some part in the increase of the strand ultimate to 34 tons, because he had realized that margins were rather small. He had discussed this with the manufacturers and they increased their tensile strength, although the figure of 32 tons remained in the documents. So he had known about this, and it had comforted him, as he believed it had also comforted Mr Sørensen.

182. The provision of extra cables was a very good thing but it was not so easy to provide as it sounded and it could often cost more money in the complication of design than might be justified in the final event; because, after all, they did not have to rethread many cables at Narrows, and subsequent jobs had been even better, so he felt that this difficulty had been overcome.

183. Mr Harris had mentioned the question of the panels. He had had this argument before, and as far as he was concerned it had originated with a representative of the "Architectural Review", who had said that one ought to express the structure and that it was wrong to decorate with non-structural panels. Quite apart from the fact that the clients quite definitely said they wanted a bridge which was smooth and sophisticated and would not have liked it otherwise, he thought there was justification, because there were many instances in life which showed that cladding could reveal the essential structure better than the omission of the cladding. There were certainly other sites where a bridge of the kind mentioned by Mr Harris would be appropriate.

184. On the question of shrinkage and cracking, raised by Mr Marsh, the greatest factor here was the one mentioned in the paper—the very high temperature and the rather rich mix. They had in fact intended to use a vibrated mix of fairly dry content, which was used on the test beam with great success, but somehow the site started with a colloidal grout and as they were being so successful, no objection was raised. But the richness, wetness and very high sun temperatures, in the 120's, were contributory factors to the crack formation. Hammersmith Viaduct had not yet shown a similar type of crack. Incidentally it should be said that these cracks were not more than ten-thousandth of an inch, they were quite small. The test beam showed no shrinkage cracks, and, as Mr Marsh had said, the many bridges built in Belgium on similar principles, using wires instead of strands, were free from cracks, although there was a difference in that most of the Belgian bridges, certainly the older ones, had the cable simply encased independently of the bridge deck itself, whereas at Narrows and other bridges the cables were bonded to the webs.

185. Mr Marsh's suggestions about using the creep losses to assist in closing the cracks were very useful but they might have disadvantages in terms of loss of prestress that would more than outweigh the advantage. He thought that by careful methods of placing the concrete by greater vibration and by using drier mixes the problem could be overcome.

186. The creep shortening of $\frac{1}{2}$ in. was an interesting figure. Again, he had not heard of it before and could not say whether it was good or bad, but he had the impression that it was about half of what they expected. It certainly seemed a very small figure. He thought it was reasonable that it had occurred during the summer, because this was a period when the greatest drying out of the bridge took place, and creep losses increased as the free water in the concrete decreased.

187. Mr Ove Arup was not right in assuming that changes were made in the road layout that the client desired. The bridge and roads as built were exactly as planned before 1955 and the reduction in skew was achieved by altering the line to which the river banks were reclaimed. This was done after the authors' preliminary skew design had been agreed in principle with the client.

188. But Mr Gifford could not understand how Mr Arup's proposed method of dealing with the skew did in fact simplify design and construction.

189. It would seem that the "warping" of the soffit would involve the contractor in shuttering complications far in excess of those of a normal skew bridge, which were difficult enough particularly when cantilevering out.

190. If Mr Partridge would refer again to § 67, he would see that the designers did relax the overall dimension tolerance from $\pm\frac{1}{8}$ in. to $+\frac{3}{8}$ in. and -0 in. but that the thickness tolerance remained at $\pm\frac{1}{8}$ in. This relaxation did result in the possibility of steps of up to $\frac{3}{8}$ in. occuring between units at the underside of the top flange but by careful adjustment in placing the units this difficulty was reduced.

191. It was found that these tolerances were practical, using timber moulds.

192. Mr Gifford agreed that robust, well made moulds were necessary to achieve this tolerance but considered that the strength was also needed to withstand the heavy vibration required to compact high quality concrete.

193. The additional cost of such moulds was more than offset by the economies obtained in weight-reduction over long spans. But this cost would embarrass a contractor who had not allowed for it in his tender.

194. The simple answer to Mr Partridge's question was that the contractor should allow for producing the units as specified. If he believed that certain tolerances were really impracticable then he should state this to the Engineer during the tender period. If the contractor was correct and if the tolerances could be relaxed, then that was the time to make such changes.

195. Mr Gifford pointed out, however, that the stresses used on Narrows bridge might well be doubled in the next few years so that even heavier moulds would be needed to achieve greater compaction and even more precise units. Prestressed concrete made with such techniques would allow the economical construction of concrete bridges of well over 1,000 ft span.

Paper No. 6486

New premises for the North Thames Gas Board, Fulham†

by

Alec James Leggatt, B.Sc., M.I.C.E.

and

Jan Bobrowski, B.Sc., A.M.I.C.E.

Discussion

Mr Leggatt, introducing the Paper, said that the main purpose of the meeting was the discussion and he would waste no time in repeating what was in the Paper. He preferred to indicate one or two lines of thought which he hoped members would follow and which would instigate some lively discussion.

89. The first concerned how a modern building should be used. Nowadays problems of stability and durability were routine matters which did not present insurmountable difficulties. Apart from the visual effect, the success or failure of a building depended largely on whether the building proved convenient in use.

90. In this matter a very great responsibility had to be borne by the owner of the building. The architect could help to a certain extent with his experience of other projects and other clients and their problems, but it was the person who had to use the building who ought to know best the requirements which it had to meet. Even so, with the best will in the world, no user of a building could predict how the pattern of his business or use would change in the distant future. Modern buildings had an expected structural life of several hundred years. Who could predict how the use of that building would change in that period? It was true that the financier talked in terms of amortization in decades rather than centuries, and if a building would function satisfactorily for 30 or 50 years, that was the extent of his interest. But the building designer should bear in mind a longer period than this.

91. The only solution to this problem was to incorporate in the design as much flexibility of planning as possible. The flexibility in the North Thames Gas Board building was a prime requirement of the client for more short-term reasons, but this theory of flexibility for the future might warrant more universal application. The Authors would particularly welcome the views of speakers on this subject, especially from those who were concerned with the problems of planning a building and using it when built.

92. The second point on which the Authors would welcome comments was that of the internal column. The vast majority of multi-storey buildings had a width—the distance between the external wall and the opposite external wall—of 40 to 50 ft. This included schools, hospitals, offices and—more recently—multi-storey car parks. Nearly all these buildings, either existing or under construction, had one or more internal columns in their cross-section, and yet very rarely were these internal columns strictly necessary. The question was, how much inconvenience did these columns cause to the user of the building and what value would he place on their absence? The Authors would welcome the views of occupiers of modern buildings on this question.

93. The other side of the question was what extra cost, if any, was placed on the

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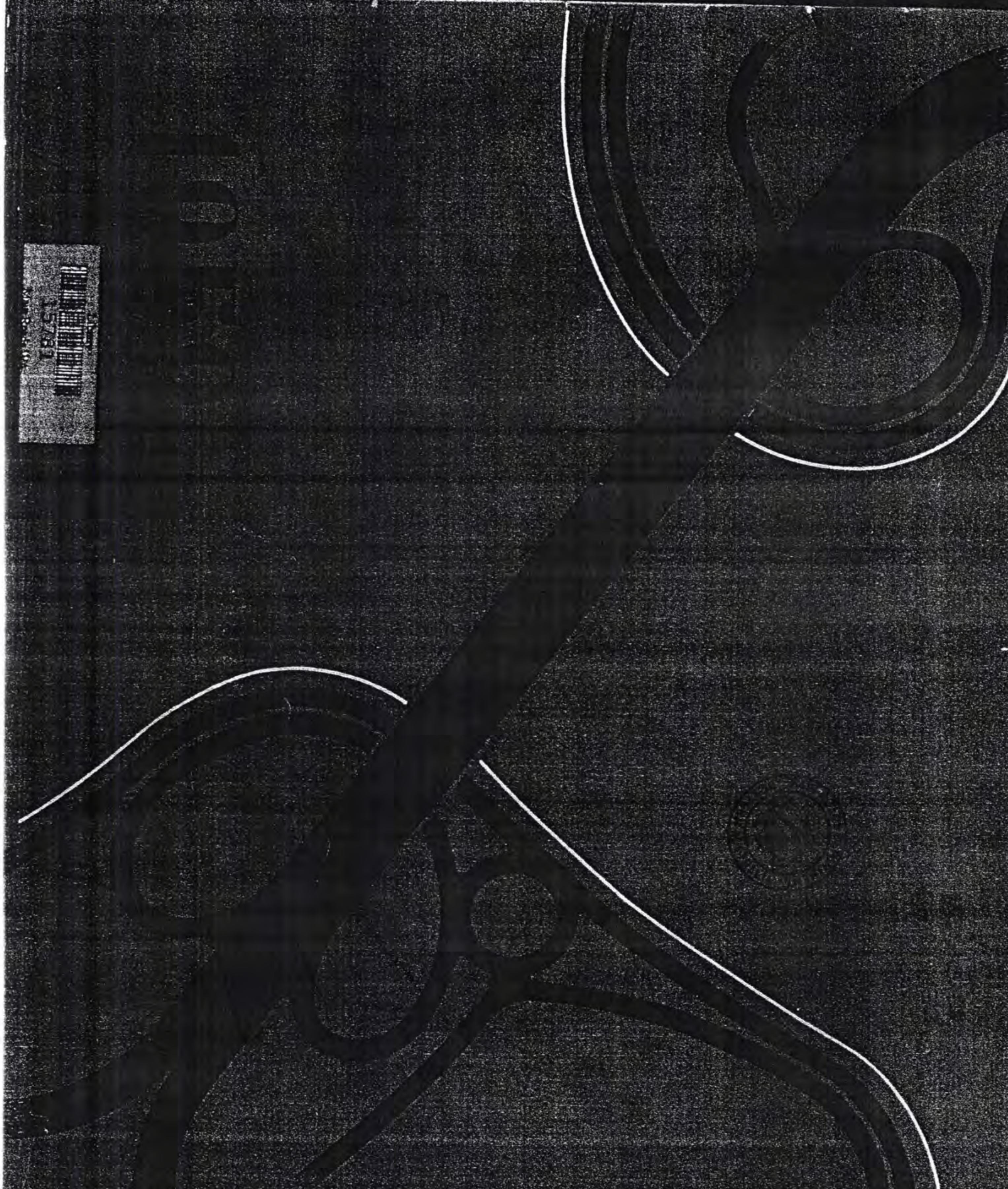
† Proc. Instn civ. Engrs, vol. 20, pp. 85–106 (Sept. 1961).

ATTACHMENT 6

OFFICIAL OPENING BOOKLET



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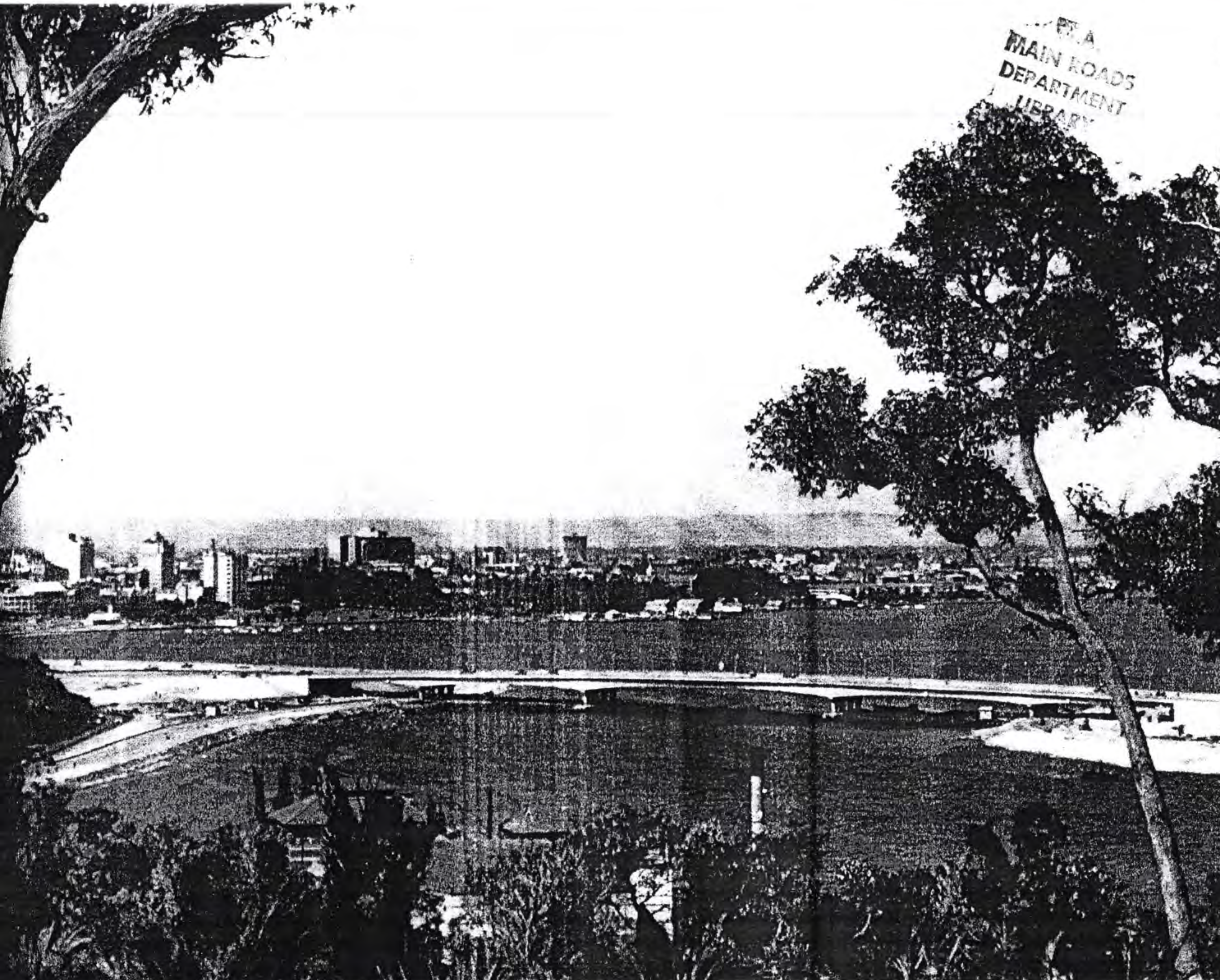

W.A.
MAIN ROADS
DEPARTMENT
LIBRARY

The Hon. D. Brand
PREMIER OF WESTERN AUSTRALIA

The Hon. G. P. Wild
M.B.E.
MINISTER FOR WORKS

The Hon. C. C. Perkins
MINISTER FOR TRANSPORT

Order of Ceremony

THE OFFICIAL OPENING

OF THE NARROWS BRIDGE, PERTH

13th NOVEMBER, 1959, AT 10.30 a.m.

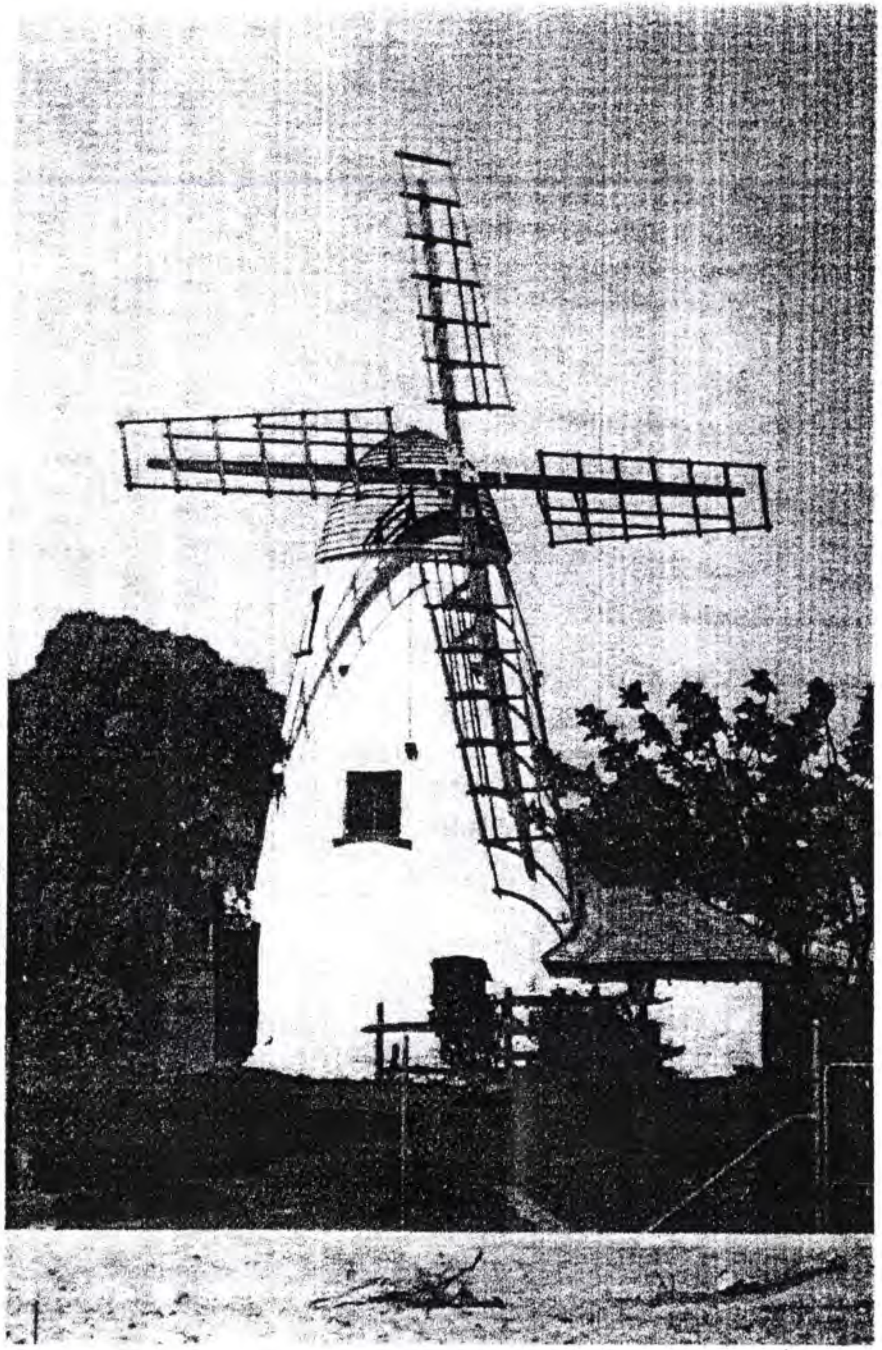
Address: Mr. J. Digby Leach, Commissioner of Main Roads, Western Australia

Address: The Hon. D. Brand, M.L.A., Premier of Western Australia

Address: His Excellency the Governor of Western Australia
Sir Charles Gairdner, K.C.M.G., K.C.V.O., C.B., C.B.E.

Unveiling of Plaque and Official Opening of the Narrows Bridge
by His Excellency Sir Charles Gairdner

Official Party complete the drive across the Bridge



The Old Mill at the southern abutment of the bridge

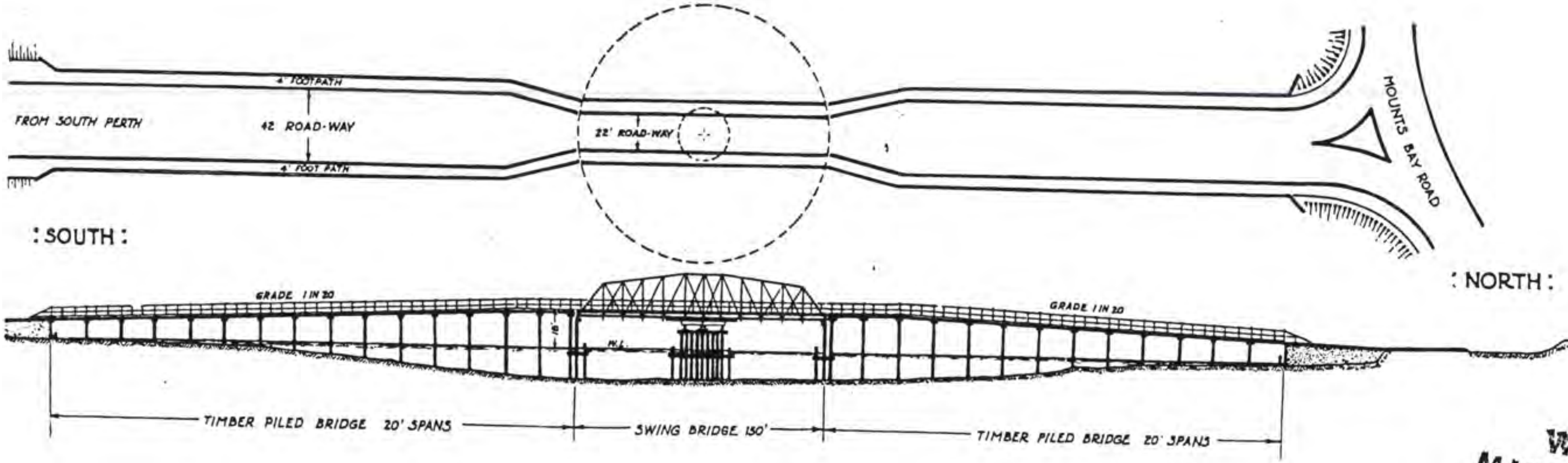
Historical Preview . . .

THE NARROWS BRIDGE is sited in an attractive scenic setting which is also an area of some importance in the historical tradition of Western Australia. At the southern abutment of the bridge, the Mill Point-Point Belches area was the site originally chosen by William Kernot Shenton for the construction of a mill for grinding cereals. Shenton's first mill at this site was completed in 1833, just four years after the establishment of the Swan River settlement.

In 1834, a group of natives from the Murray River tribe attacked and robbed the mill. In the following year, the original mill was replaced by a picturesque stone structure which has been preserved to the present day.

The potentialities of the Narrows site for facilitating transport movements to the then isolated area between the Swan and Canning Rivers were visualized as early as 1834 when a ferry was established from Point Belches to the foot of Mt. Eliza. The route followed for land travel between Perth and the area bordering the confluence of the Swan and Canning Rivers had been via Guildford, a total distance of some eighteen miles which was considerably shortened by the use of the ferry. However, the ferry ceased operating after a few years service as the first Causeway bridges were completed in 1843.

In September, 1849, an article appeared in the weekly newspaper, " The Inquirer," the forerunner of the present " Daily News," commenting on the desirability for constructing a bridge at the Narrows and this was followed a month later by a letter from a correspondent. " Viator," who advocated that the Narrows should be bridged to provide " a line of communication between Perth and Fremantle in lieu of the present tedious and protracted route via the causeway," and that when the work



Plan and profile of proposed timber bridge and approach roads, designed by the Public Works Department in 1901, to cross the Narrows

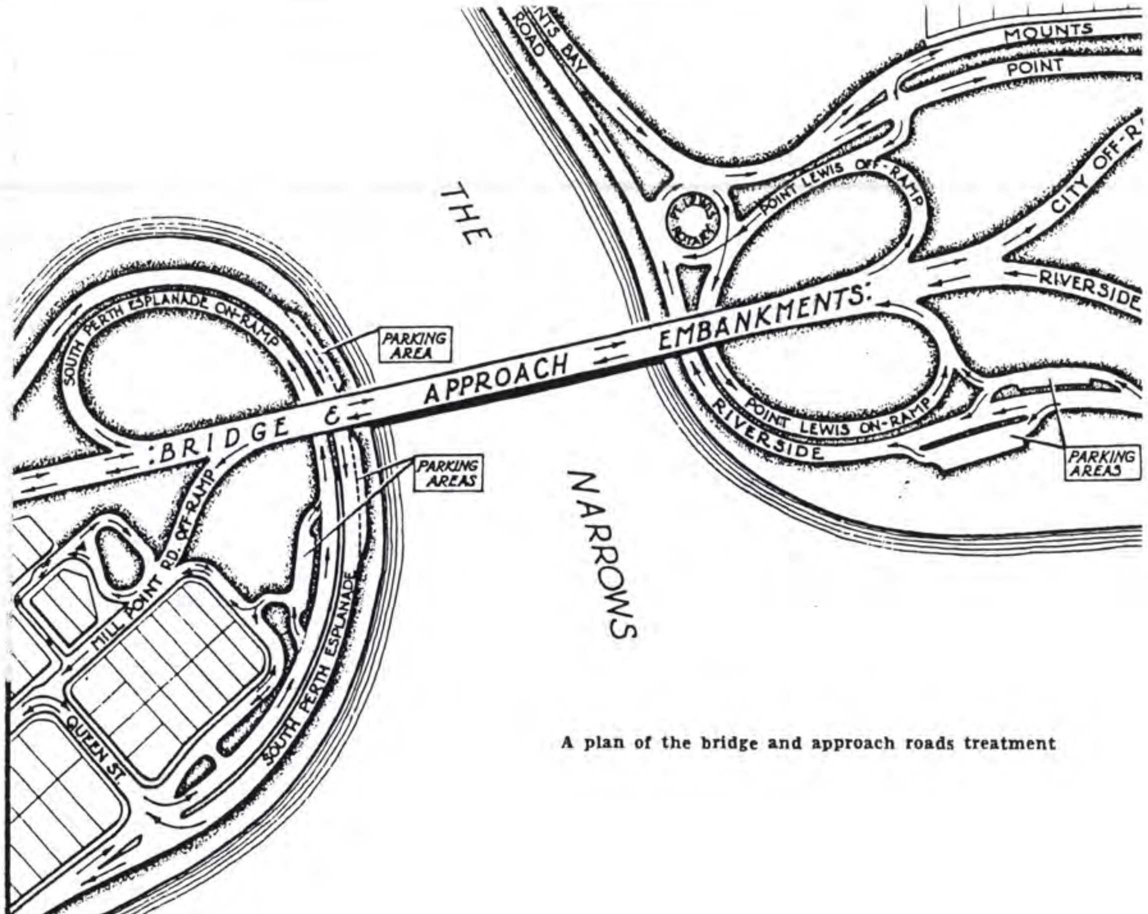
was undertaken " it should be put under proper professional control that our colony may be no longer (so justly) reproached for its mushroom and defective works."

By the 1880s, when the Alta Hotel and gardens were established at Mill Point, the area was regarded as an attractive picnic, crabbing and boating centre. The name of the gardens was later changed to " Cremorne " and an advertisement in " The West Australian " during October, 1885, for the sale of property at Mill Point referred to the possibility of a bridge being built at the Narrows as " almost a certainty."

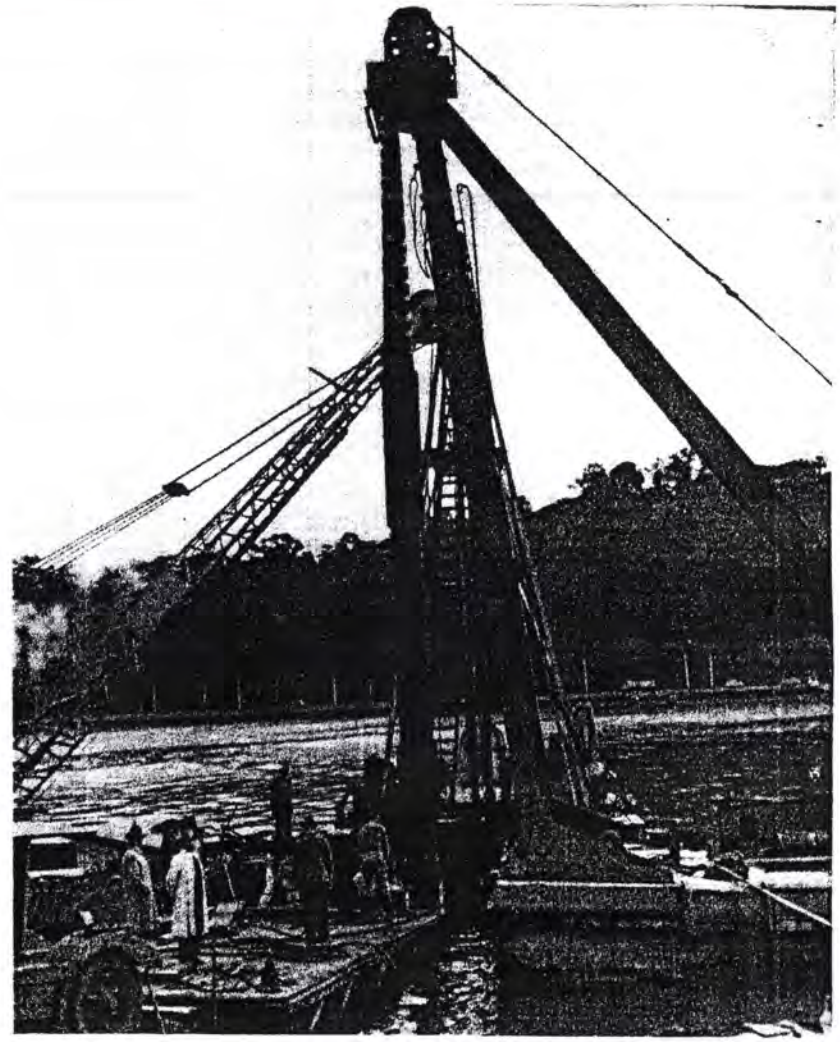
The Public Works Department prepared a sketch plan for a bridge at the Narrows in 1901. The design provided for a timber, pile driven, bridge structure and through navigation was to be provided by means of a central swing span. However, the time was not regarded as appropriate for such a structure so the plan was shelved.

Residents of South Perth had been most vocal over the years in advocating a direct river crossing to the city. In a report issued by the Metropolitan Town Planning Commission in 1930, proposals for an alternative traffic outlet across the river were discussed. With regard to the possibility of crossing the Swan River at the Narrows the Commission suggested " that this position affords a natural and necessary opportunity for linking both sides of the Swan River " but it was not prepared to make a recommendation as to what form this crossing should take.

Despite the interest shown since the year 1849 in bridging the Narrows, nothing concrete eventuated until after World War II. While this historical preview would appear to substantiate the saying of Robert Benchley that—" It has always seemed to me that the most difficult part of building a bridge would be the start "—a beneficial effect of this delay in bridging the Narrows is that this State has now been provided with a bridge which embodies the latest conception of structural design in a slender superstructure system of prestressed concrete, a medium of construction which is only of recent development.



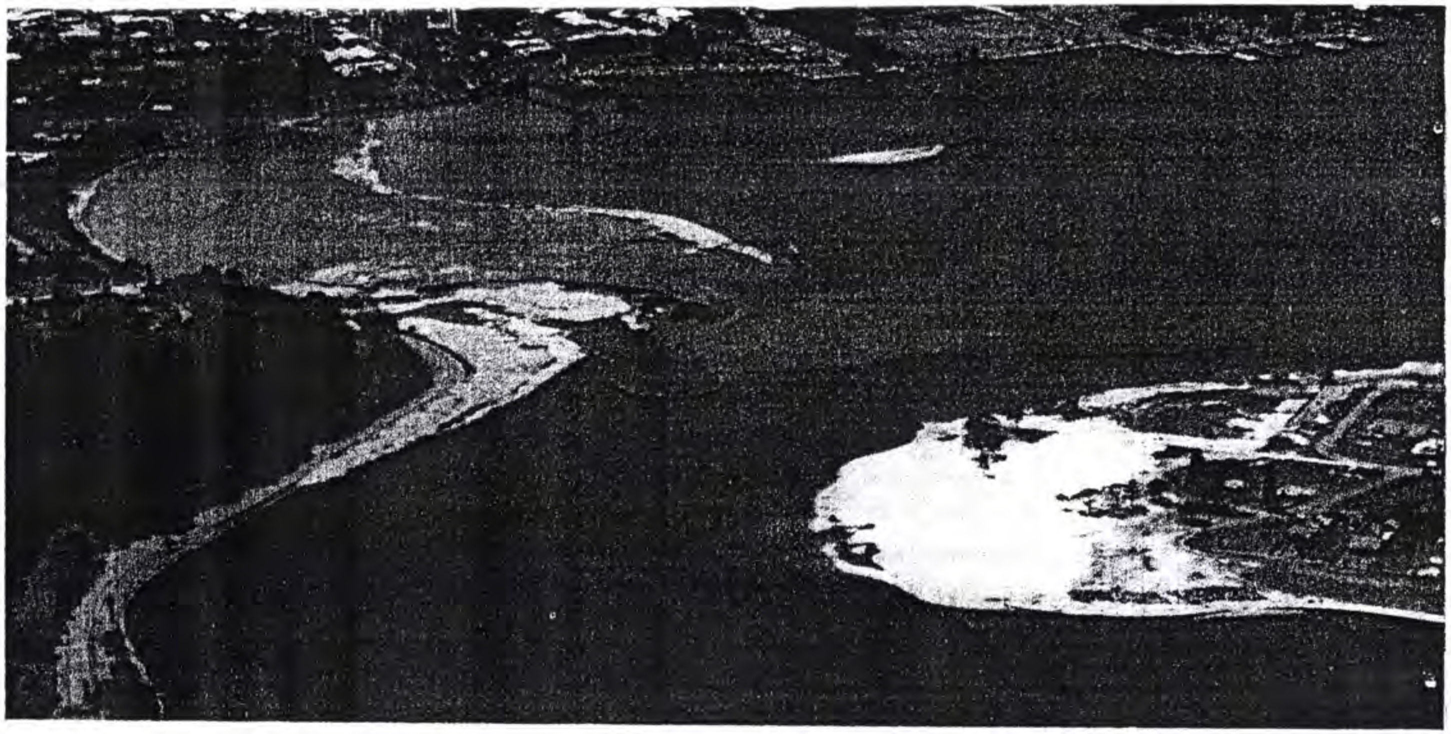
A plan of the bridge and approach roads treatment



Driving a test pile in 1956 for the Main Roads Department

Planning the Bridge . . .

PRELIMINARY REPORTS and sketch plans for a bridge at the Narrows were prepared by the Main Roads Department in the period 1947-1953 but the project was postponed as the Department's resources were fully occupied in the building of the new Causeway. Suggestions



Reclamation work in progress for the approaches to the bridge

—*W.A. Newspapers photograph*

for an alternative crossing of the river to the Narrows site were also investigated by the Main Roads Department during this period. In order to co-ordinate the planning for a new traffic crossing to the city with the overall town planning scheme for the metropolitan region, proposals for an additional crossing of the river were discussed with the Town Planning Consultant and Commissioner in 1953.

A report based on the findings of a traffic survey was submitted in 1954 which revealed that traffic on the Causeway had more than doubled in less than five years and that the Causeway rotaries and Canning Highway were fast reaching saturation. The provision of a bridge at the Narrows was therefore a matter of some urgency. In August, 1954, the Government approved the recommendations of the Main Roads Department for the bridging of the Narrows and test boring of foundation conditions and reclamation work were commenced.

The Main Roads Department had worked in close collaboration with the Public Works Principal Architect and the Town Planning Department and their Consultant and it was agreed that the bridge design should provide for slender spans of maximum length in order to harmonize with the aesthetics of the scenic site. Due to the difficult foundation conditions and design requirements, investigations were made by the Department's Bridge Engineer in Europe and the U.S.A. In September, 1955, Maunsell and Partners of London were appointed Consultants to the Narrows Bridge project and were commissioned to prepare the design and detailed plans for the construction of the bridge. The design for a prestressed concrete bridge which provided for a slender, elegant structure of five spans as suggested by the Department was submitted by the Consultants and approved by Cabinet in April, 1956.

Mr. Ott Nilsen (left), of Christiani and Nielsen, and Mr. W. Clough, of J. O. Clough and Son, discuss, on the site, the construction of the bridge

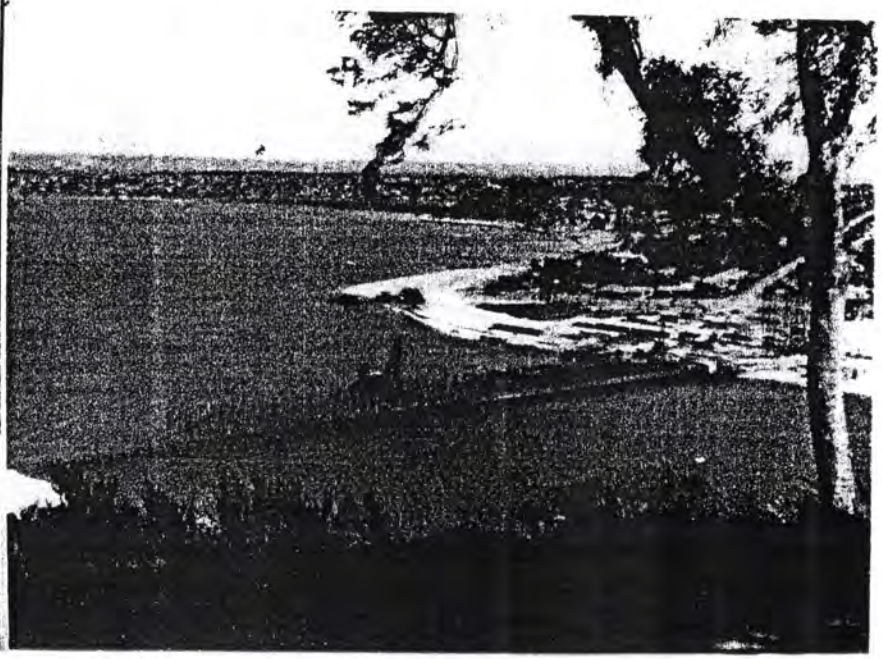
—*W.A. Newspapers photograph*

Construction Begins . . .

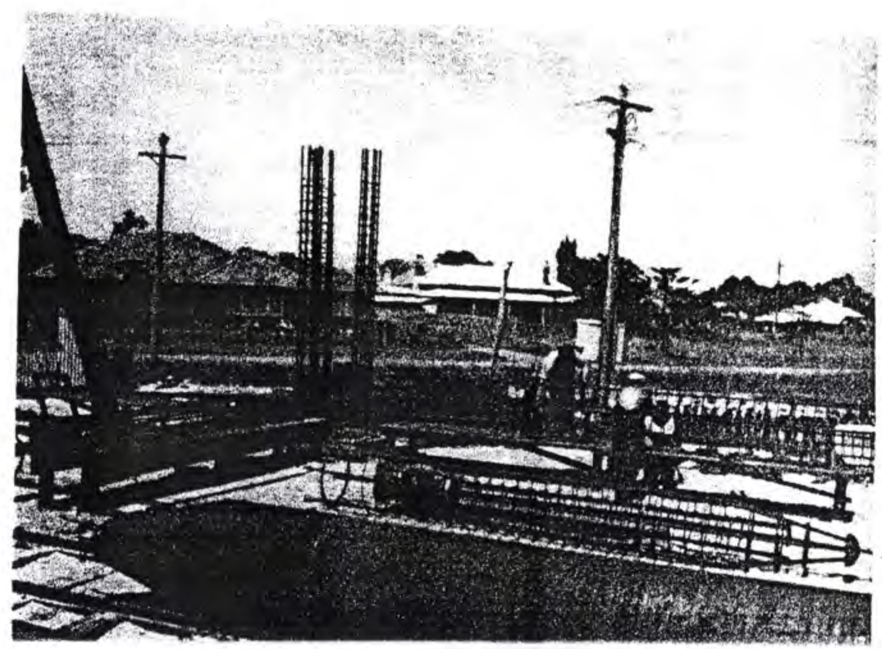
A PRELIMINARY ANNOUNCEMENT to contractors indicating the nature of the work was advertised in the United Kingdom, Europe and the U.S.A. in July, 1956, and tenders were then called. The lowest tender of £1,325,000, which was submitted by Christiani and Nielsen of Denmark in association with J. O. Clough and Son of Perth, was recommended by the Consultants and accepted by the Government on the 12th March, 1957.

Reclamation work, undertaken by the Harbours and Rivers Department had been proceeding since 1954 and

Erection of the timber pile staging as a temporary support for the superstructure beam units —*W.A. Newspapers photograph*

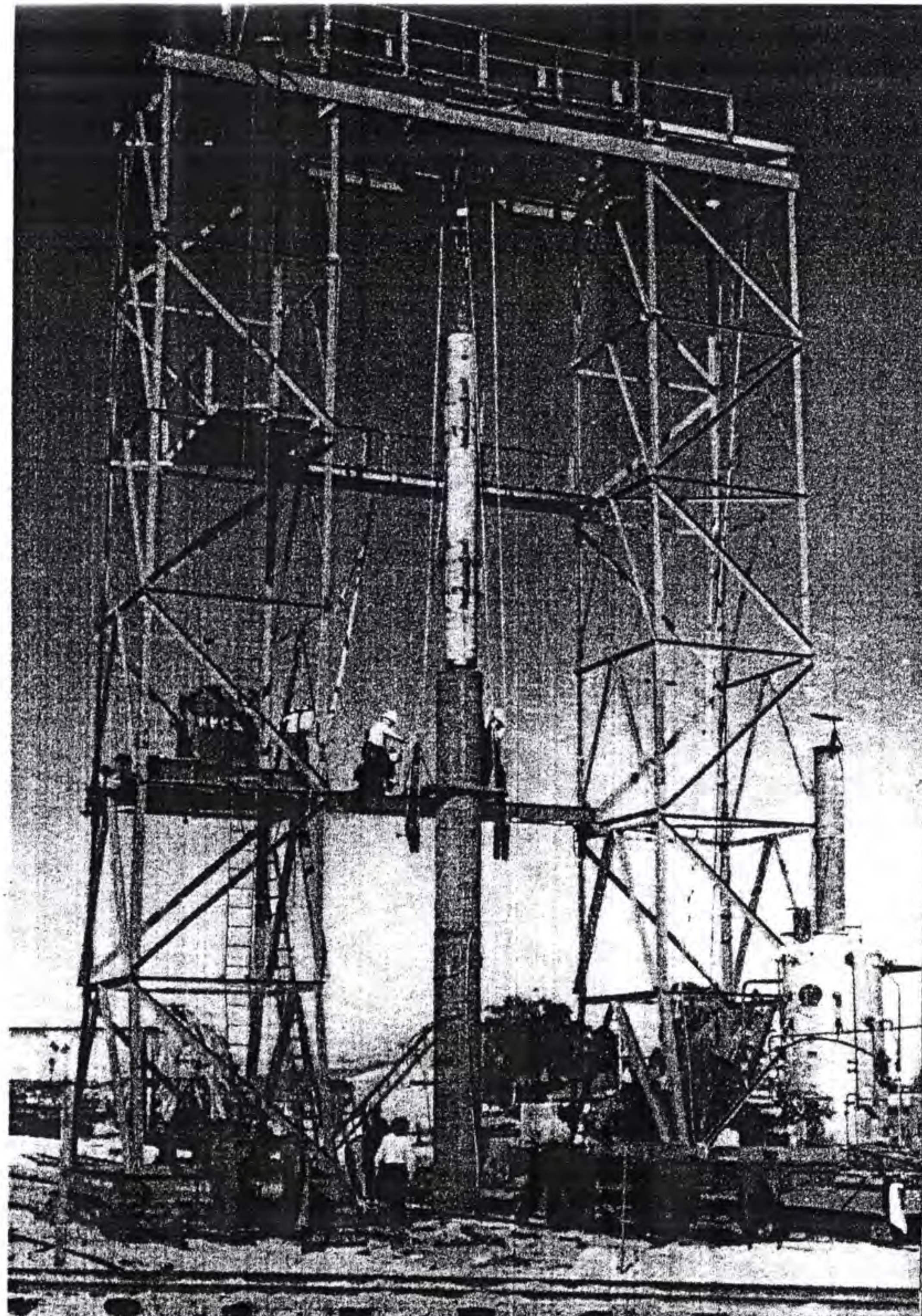


Bottom section of gambia pile



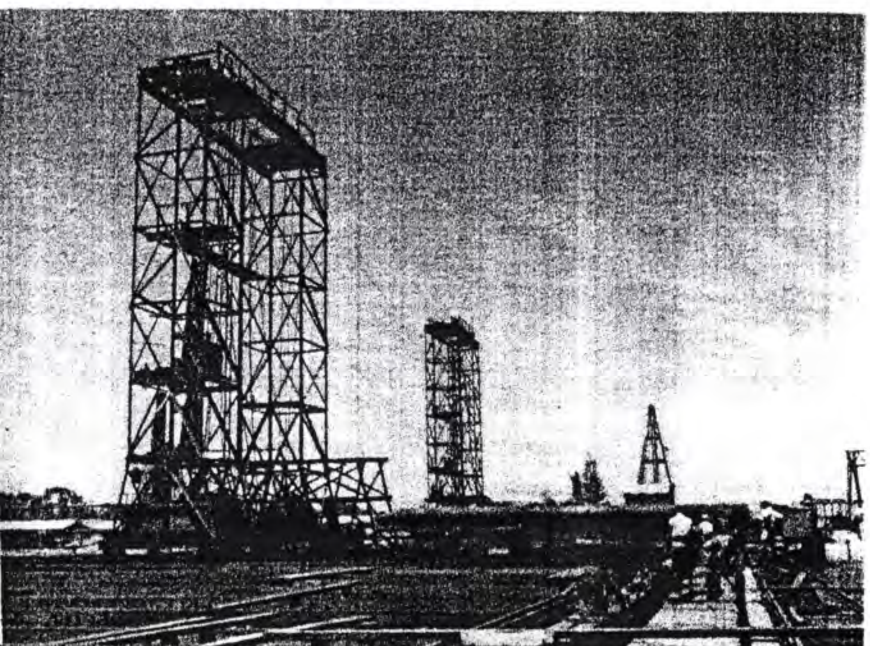
Gambia pile casing with ten ton drop hammer used for driving

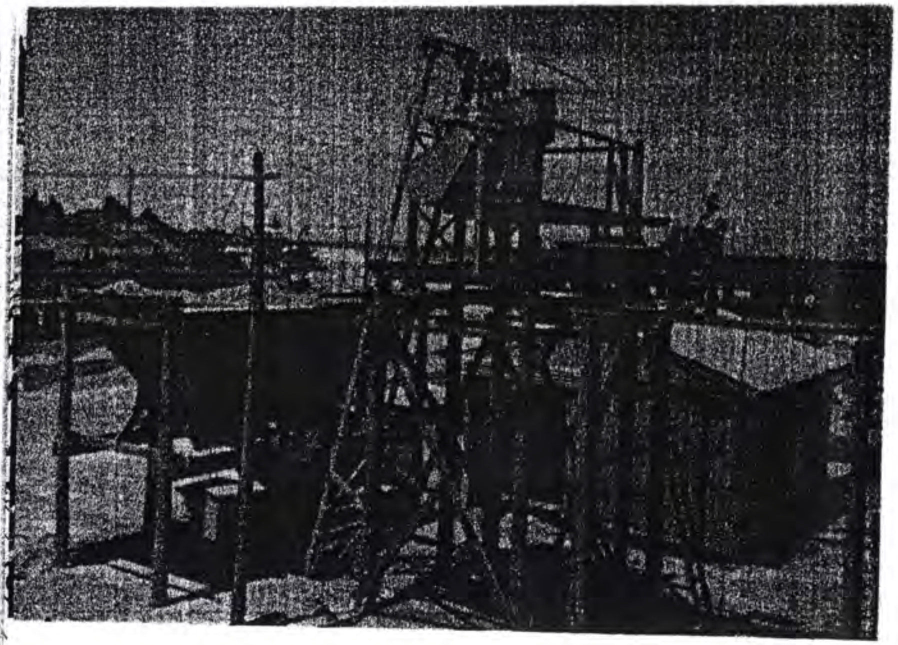
—*W.A. Newspapers photograph*



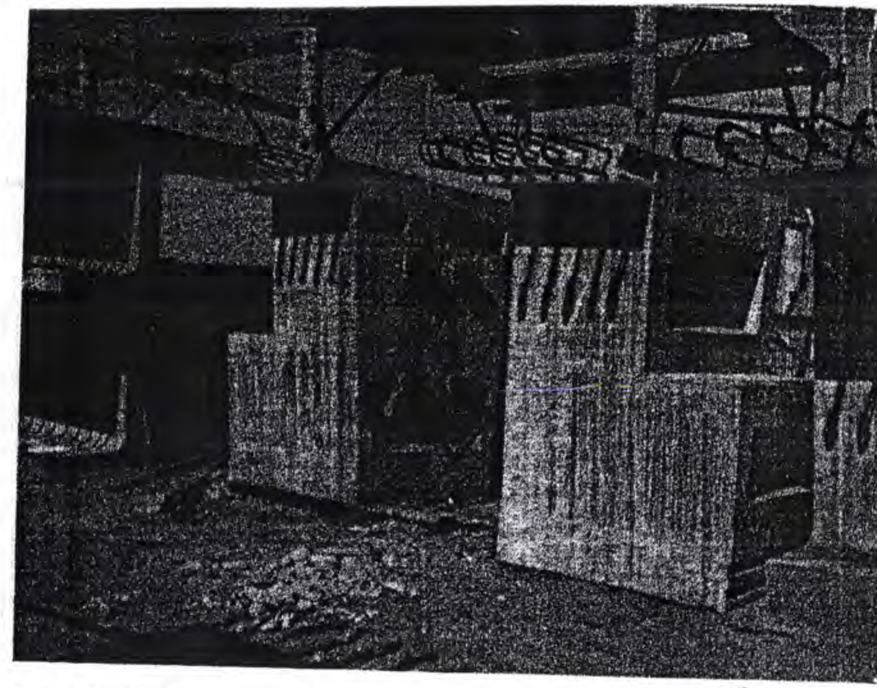
construction of the timber pile staging as a framework for the bridge structure commenced on the 7th June, 1957. The first of the permanent piles, on which the bridge piers and abutments are supported, was driven in August, 1957. These piles, referred to as "Gambia" piles after the territory in Africa where the type was first used, consist of a hollow cylindrical steel shell 31 inches in diameter with a conical nose. The "Gambia" piles were driven through some 60 feet of organic mud into underlying layers of sand to an

Gambia pile being moved into position preparatory to driving

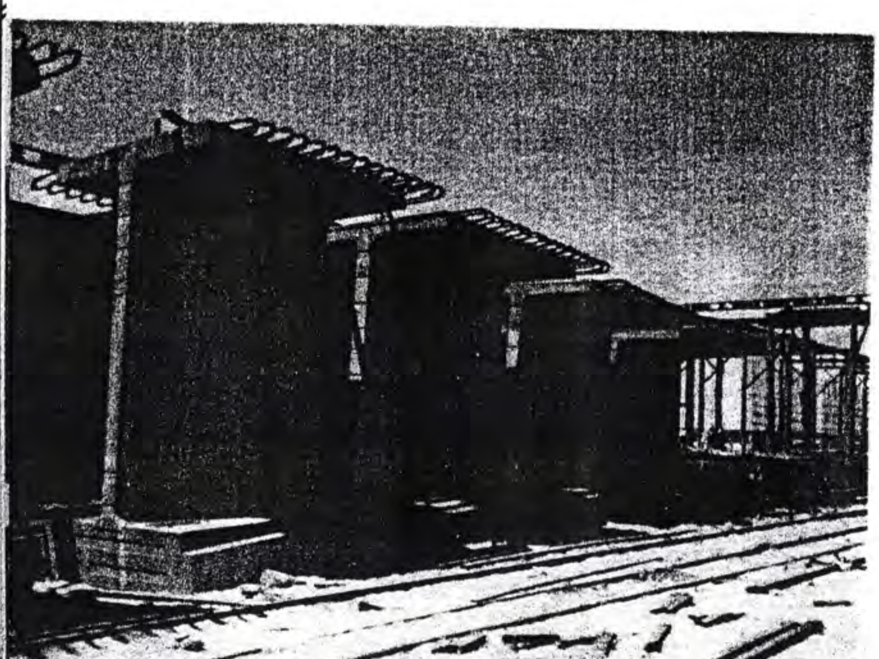




Concrete mixing plant located in the casting yard



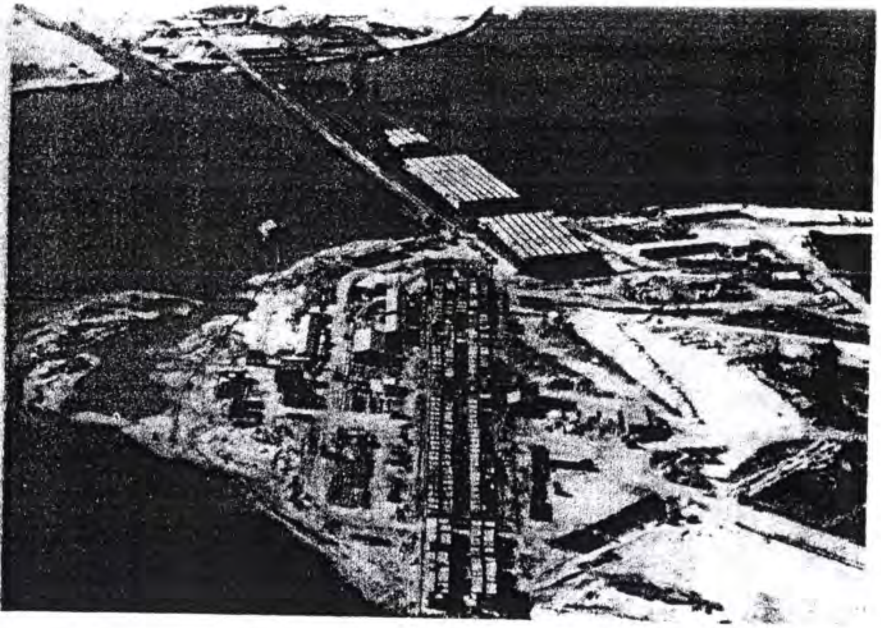
Precast blocks for anchoring prestressing strands



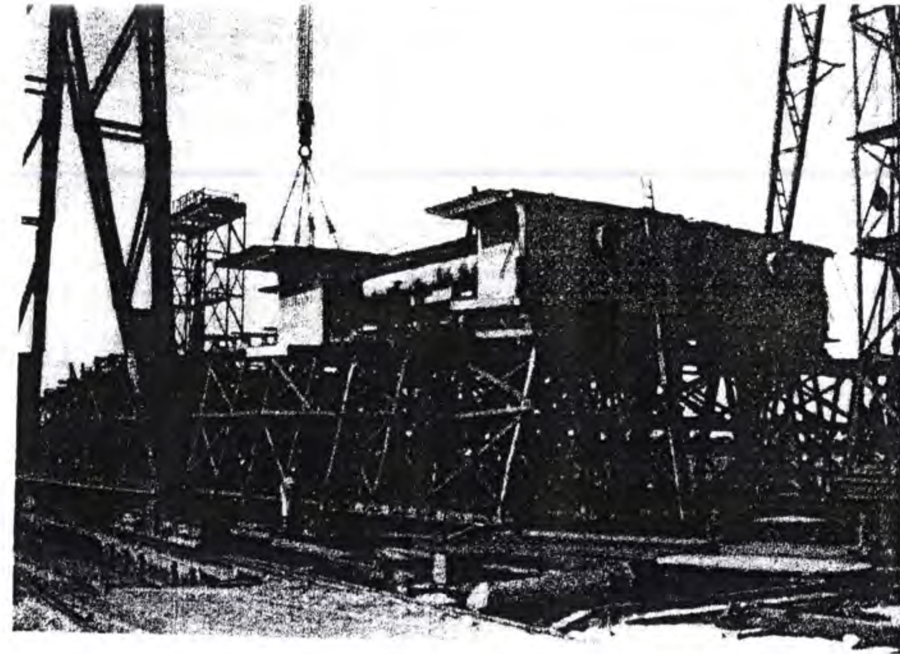
Precast concrete beam units stacked in the casting yard

average depth of 110 feet below water level. They were then filled with re-inforced concrete. Each of the two river piers consists of 32 piles designed to accommodate a total load of 6,400 tons.

The piles were then capped with a 4 ft. thick slab of re-inforced concrete which in turn was surrounded by precast skirting slabs. At each pier, the pile cap carries four triangular shaped columns of re-inforced concrete, providing an open type of pier structure which ensures a view

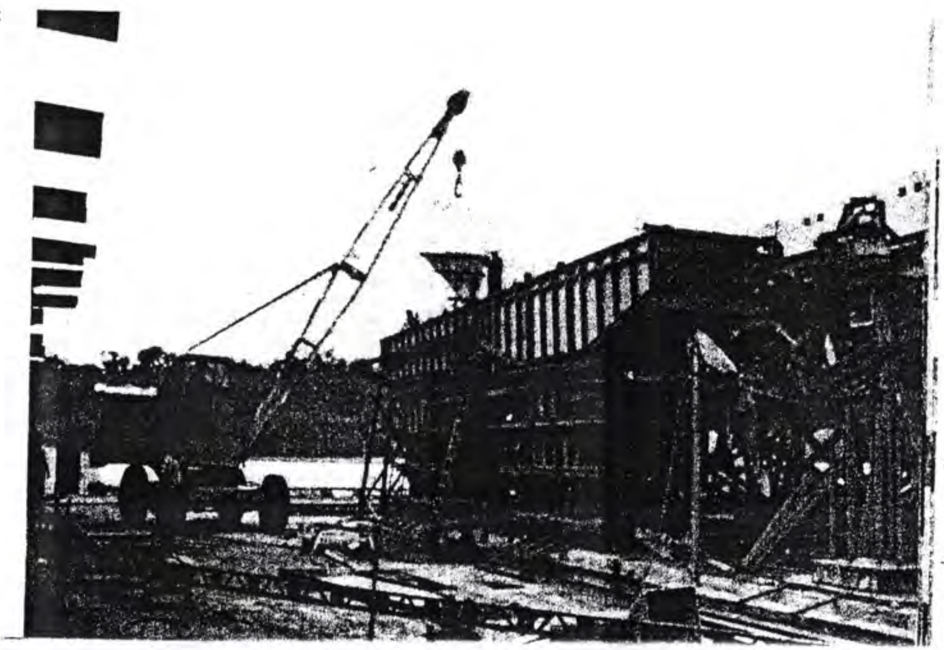


A view of the precasting yard and progressive assembling of the bridge sections

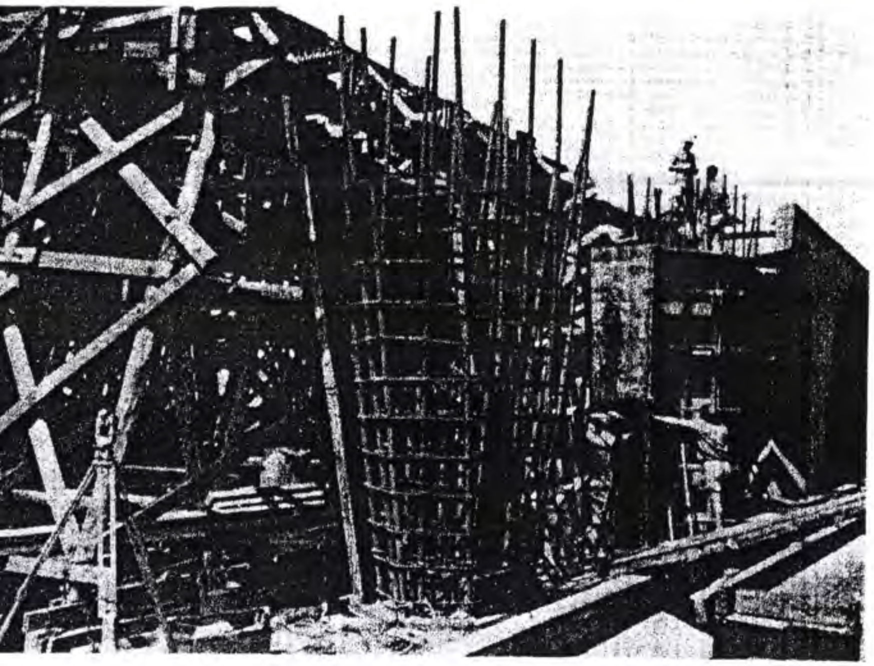


Precast beam section being lifted into position

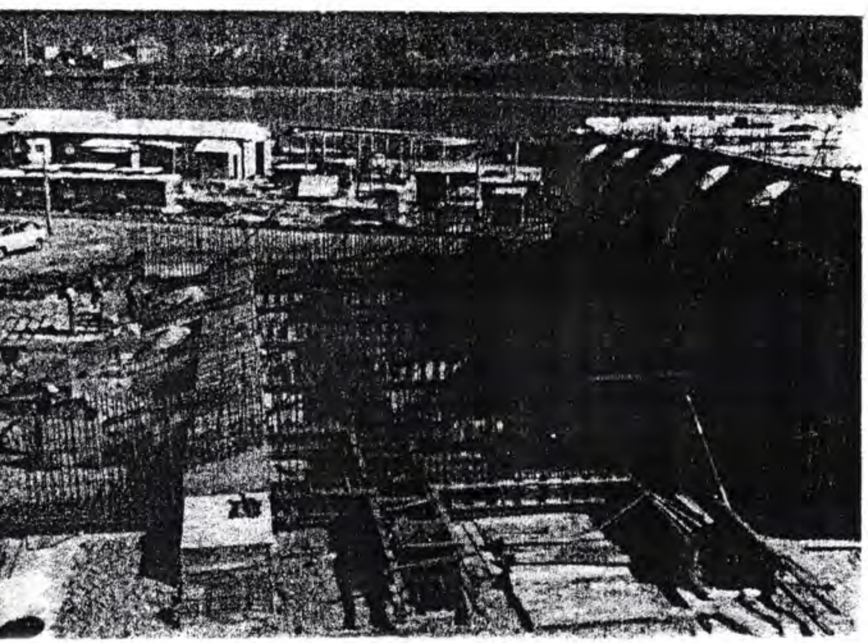
through the piers themselves. The head of each column carries two lines of longitudinal beams in the superstructure. The slenderness of the structure is indicated by the depth of these sections, being 7 ft. 4 ins. at the centre of the bridge. The superstructure is designed to be structurally continuous over its full length of 1,100 feet. It is "fixed" at the northern end so that at the southern end and at the intermediate pier columns provision must be made for movement relative to the foundations due to change in length



Pier column form work



Pier column re-inforcement and completed columns

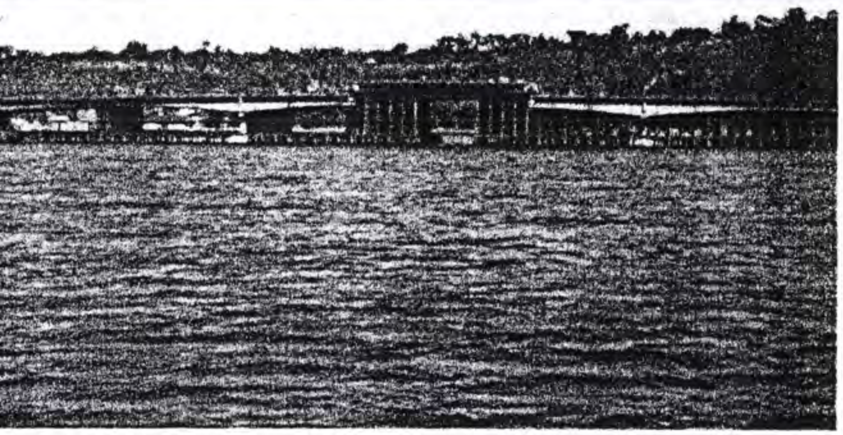


Construction of southern abutment

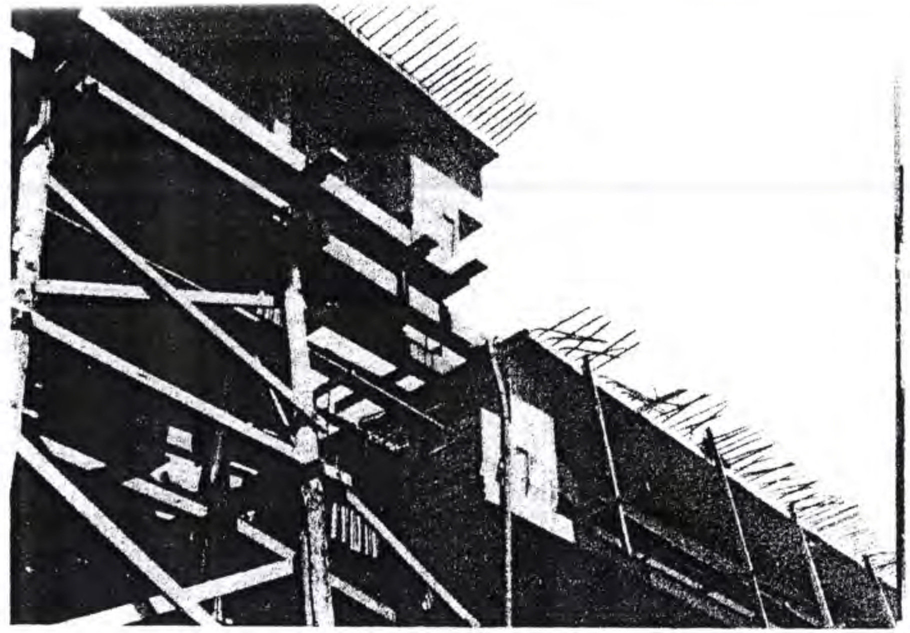
An inspection of the site by some of the men responsible for the bridge project. From the left: Mr. Ott Nilsen, of Christiani & Nielsen, the then Minister for Works (Mr. J. T. Tonkin), Mr. T. Bingham, of Maunsell & Partners, Mr. J. Digby Leach (Commissioner of Main Roads) and Mr. W. Clough, of J. O. Clough & Son

—*W.A. Newspapers photograph*

because of temperature variations. This change, estimated at $3\frac{1}{2}$ inches either as shortening or lengthening at the southern end with lesser amounts at the piers, is accommodated at the south abutment on rollers and at the piers by allowing the pier columns to act as large diameter rollers. For this purpose, the upper and lower faces of the columns are provided with stainless steel plates machined on their bearing surfaces to a diameter equal to the height of the columns.

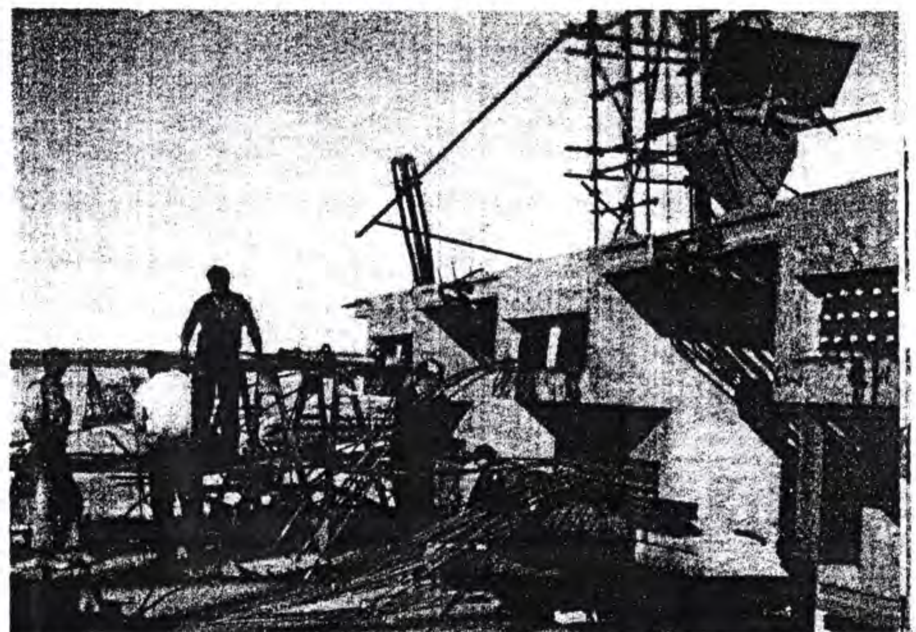


A general view during construction with the centre span elevated prior to prestressing

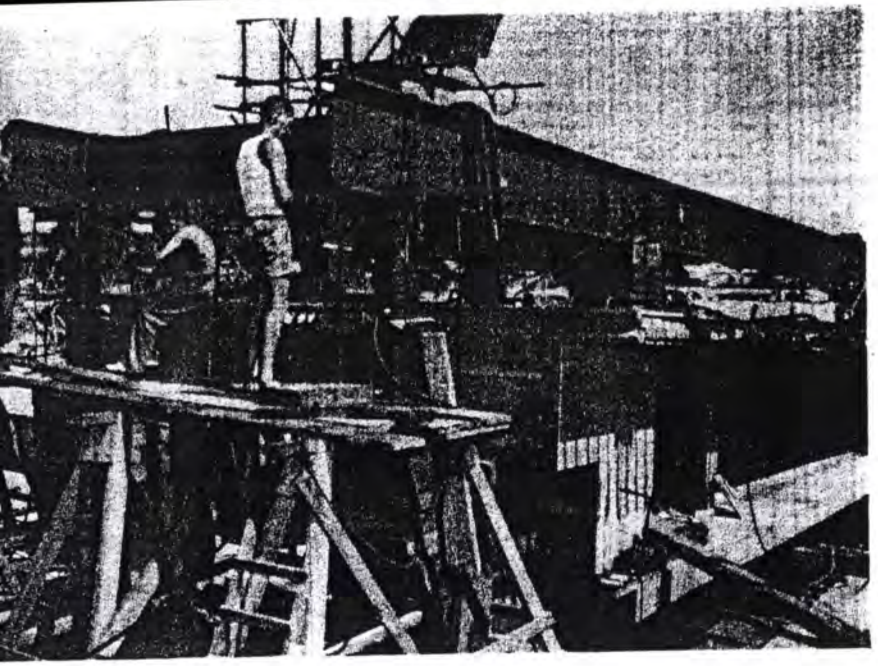


Anchor blocks in position before lowering a suspended section

The re-inforced concrete beam units used in the superstructure of the bridge were precast in the casting yard prepared by the Contractor on the southern bank of the river. To facilitate the movement of materials and bridge components, the precasting yard was equipped with overhead monorail tracks, transporter track and controlling gantry. After casting, the individual concrete deck units, weighing up to 15 tons, were transported and erected on the

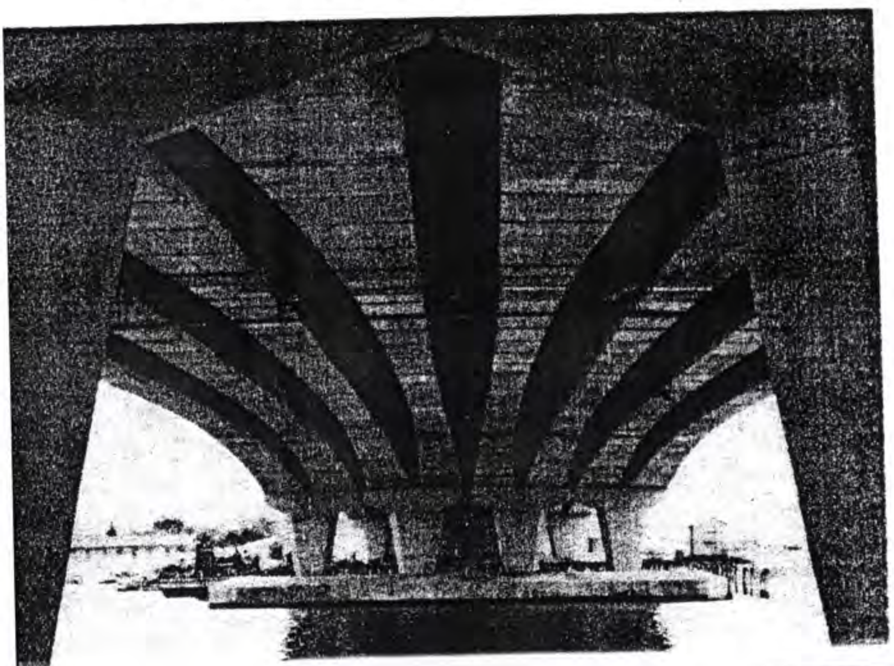


Stressing operations for uniting the bridge superstructure units



The jacking down of two lines of beams of a suspended span

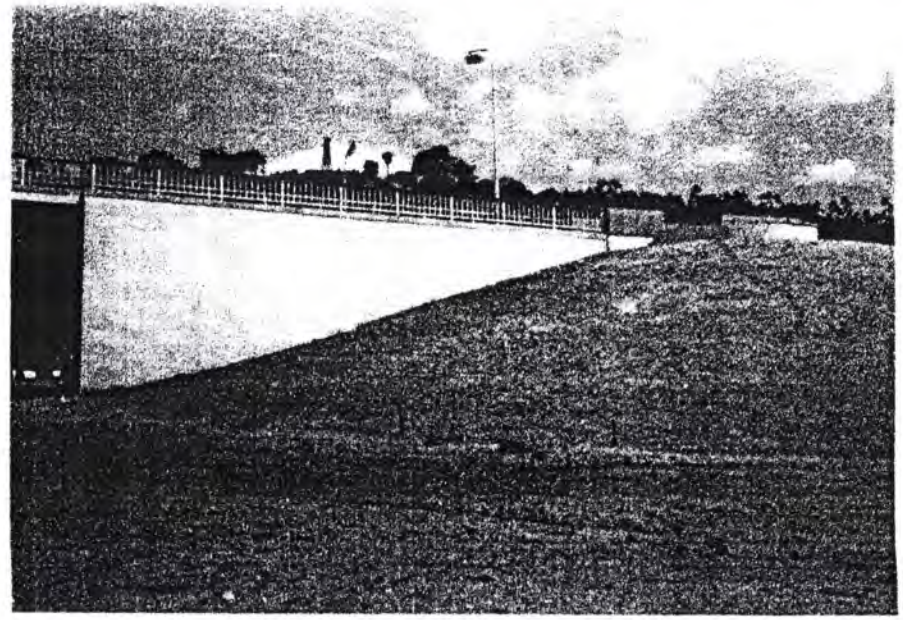
A view through the pier columns of the bridge —*W.A. Newspapers photograph*



temporary staging at the river location and were joined structurally by strands of high tensile wire placed symmetrically on both sides of the web of the beams.

The high tensile strands were then stretched by hydraulic jacks to a predetermined load and were anchored against heavy concrete blocks so that on release of the jacking loads, compression forces were imposed on the deck units. It is these heavy compression forces, reaching a maximum of 20,000 tons in the superstructure over the river piers, that unite the bridge structurally. In order to facilitate erection, each line of beam units was erected as two main spans each 370 feet long cantilevering over the river and shore piers with one central suspended span 140 feet long and two end suspended spans each 110 feet long. To enable the stressing operations to be effected, the suspended spans were erected temporarily at a higher level than the finished structure. After lowering, they were united by tensioned continuity cables. By June, 1958, precasting work

Abutment showing parallel wings and outside beam facing slabs

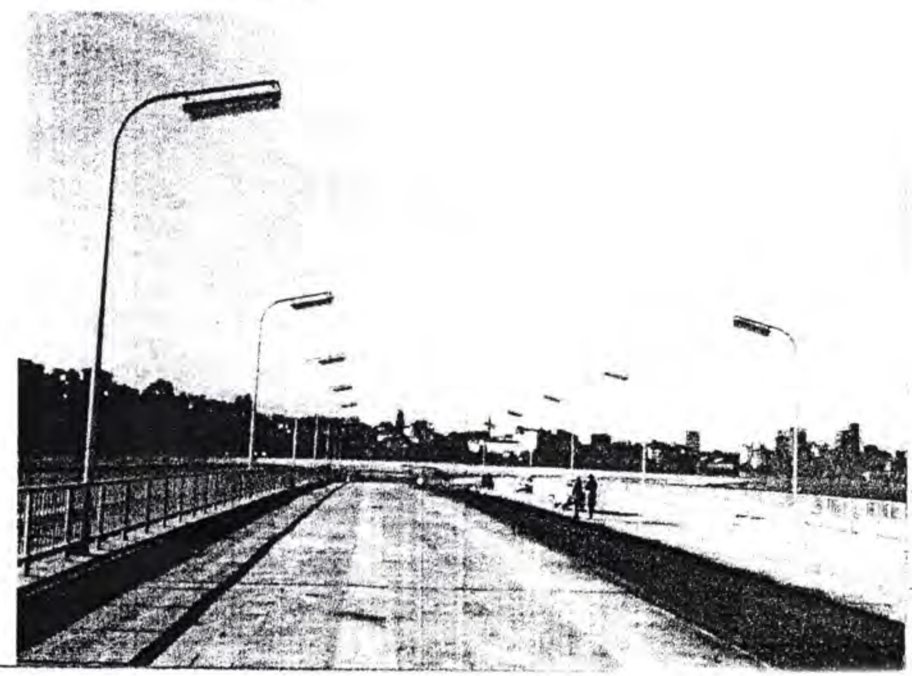


was well advanced and the first sections of the bridge had been assembled on the temporary timber staging.

The remaining sections of the bridge were assembled during the year ended June, 1959. The cantilevered footways were then constructed *in situ* from re-inforced concrete using white cement and quartzite stone to blend in colour with the side walls of the abutments. Panels of anodised aluminium were used in the construction of the safety fences and the main balustrading and a bituminous concrete carpet was then placed on the roadway of the bridge. The slender, tapered aluminium lighting standards and fluorescent lamps provide for high intensity lighting.

The appearance of the bridge blends with the aesthetics of the site by combining structural lightness with simplicity in shape and graceful proportions. This effect has been achieved in the design and construction by a delicate proportioning of the piers and superstructure and the selection of suitable materials for the outside faces of the abutments, the cantilever footways and the slabs which screen the face of the outside beams.

A deck view prior to surfacing



An inspection of the bridge works by (from the right) the Commissioner of Main Roads (Mr. J. D. Leach) and Sir William Holford and Mr. Richard Gray, consulting architects to Maunsell & Partners —*W.A. Newspapers photograph*

The Approaches . . .

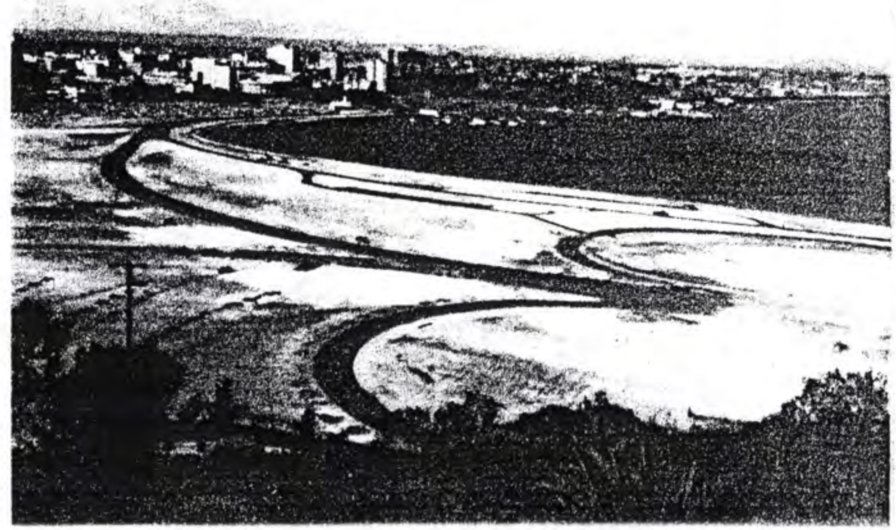
THE BRIDGE and the approach system have been designed for peak hour traffic volumes of 6,000 v.p.h. in one direction, and provision made in the design for the bridge to be operated ultimately on a 4/2 lane distribution reversed at peak periods.

The siting of the bridge in its present position has made feasible an adequate roadway of modern design from the Canning Bridge along the Como foreshore. Because this alignment was accepted, there were no major problems of resumption and severance of established land use, and it has been possible to proclaim the road a controlled access motorway and thereby make provision for free and safe traffic movement.

The problem is more complex on the north bank. The Narrows Bridge and the Kwinana Freeway form a section of a major radial highway which will carry traffic to and from the city centre. There is a major problem therefore in the dispersal and storage of vehicles once they reach the north bank of the river. A high proportion of the bridge traffic will be intercepted and stored in the large fringe car park, accommodating 2,300 vehicles, lying approximately between Spring Street and William Street.

The provision of this large fringe car park is part of the ultimate plan for city development and is an essential requirement. The need for space

The approach road system on the northern embankment



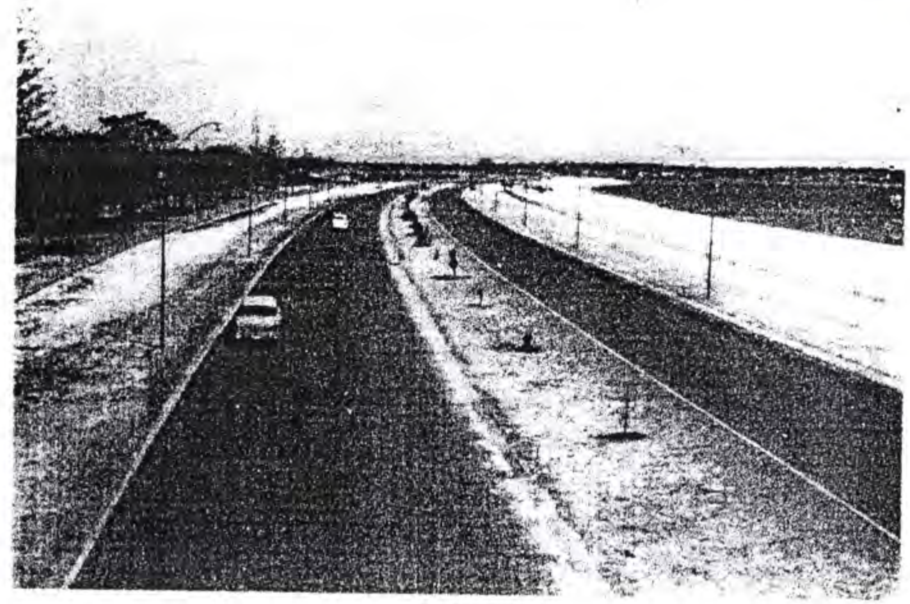
to accommodate the car park imposed a basic requirement for reclamation from the river at the car park site. At the bridge itself it was desired to avoid unsightly ramp structures, and the treatment of on and off ramps was therefore resolved by extending the ramps beyond the bridge in two spiral loops passing under the bridge structure and having their traffic conflicts resolved in a traffic rotary lying between the bridge and the bluff of Mount Eliza. Since traffic on these loops will be required to operate at speeds approaching 30 m.p.h. to be in keeping with speeds expected on the bridge and other parts of the approach system, the size of the loops was fixed mathematically, and thus a limit was set to the amount of reclamation required in the immediate vicinity of the bridge. The remaining area of reclamation became necessary to eliminate dead water and to provide an attractive curvature to the river bank between the two basic parts of the reclamation at the car park and at the bridge ramps. The reclamation was generally regarded by the citizens of Perth with dissatisfaction, but once an appreciation was made of the high traffic volumes to be handled and of the need, therefore, for grade separation and adequate storage in car parks, it was apparent there was no practicable alternative.

The ground conditions on the northern approaches to the bridge were very difficult. The shallow section of Mounts Bay was reclaimed on a depth of about 70 ft. of mud. Pumped fill was placed behind a marginal line of sand and shell placed by grab and suction dredges from stockpiled materials previously placed strategically by suction dredge. Dredging to reclaim this area was commenced in October, 1954, and was treated as a matter of urgency. An additional dredge was soon found to be necessary and dredging capacity was increased by 50 per cent. The whole quantity of dredged material estimated at $1\frac{3}{4}$ million cubic yards was pumped over a period of 42 months and completed in September, 1958. This quantity does not include the pumping of nearly 1 million cubic yards where double handling or removal of mud waves displaced by the fill was involved.

On the south bank, the Kwinana Freeway was located largely upon land reclaimed from the river by suction dredging some $1\frac{1}{2}$ million cubic yards of mud and shell from the river bed at Melville Water. The freeway which has dual carriageways is fenced on both sides and all traffic other than motor traffic is excluded from it. There are three slip-off roads leading on to the road system of South Perth, one permanent slip-on for traffic proceeding southward at Stirling Street and one temporary slip-on road at Bickley Street at the southern end for traffic proceeding northward. The latter will be eliminated when grade separation becomes necessary at the Canning Bridge intersection.

The water front of Melville Water at Como is a popular river beach resort and it was important therefore, that after the new motorway was constructed, this beach should be restored with its original amenities and with easy access.

To preserve access to the beach and provide safe crossing for pedestrians over the freeway, five concrete pedestrian bridges with helical ramp approaches were constructed. The helical ramps have been constructed with easy gradients and are of reinforced concrete. The superstructures are constructed in prestressed concrete and the structures present a light and delicate appearance.



The Kwinana Freeway as seen from a pedestrian overway

One of the five pedestrian overways—*W.A. Newspapers photograph*

A view from the bridge —*W.A. Newspapers photograph*

Bridge Contractors

CHRISTIANI AND NIELSEN OF COPENHAGEN, DENMARK
IN ASSOCIATION WITH J. O. CLOUGH & SON, PERTH

Major Subcontractors to the Bridge Project

BARRINGTON QUARRIES PTY. LTD.
BROKEN HILL PTY. CO. LTD.
H. L. BRISBANE AND WUNDERLICH LTD.
CEMENT SALES PTY. LTD.
HARBOUR WORKS PTY. LTD.
HOT MIX PTY. LTD.
J. & E. LEDGER PTY. LTD.
STATE BUILDING SUPPLIES
STATE ENGINEERING WORKS
THE STRUCTURAL ENGINEERING CO. OF W.A. PTY. LTD.
VICKERS HOSKINS PTY. LTD.
WILSON GRAY & CO. PTY. LTD.

Bridge Statistics

The bridge was constructed for the Main Roads Department of Western Australia. Consultants—Maunsell and Partners, London. The cost of the bridge was in the order of £1,500,000 and the total cost of the project including the bridge, pedestrian overways, Kwinana Freeway, approach roads, reclamation and land resumption was in the region of £3,500,000.

The Narrows Bridge

LENGTH

1,100 FEET IN FIVE SPANS. CENTRE SPAN 320 FEET WITH FLANKING SPANS EACH SIDE OF 230 FEET AND 160 FEET

CLEARANCE UNDER CENTRAL SPAN

26 FEET ABOVE NORMAL WATER LEVEL FOR A WIDTH OF 230 FEET

WIDTH OF BRIDGE DECK

VEHICULAR WAY—70 FEET
FOOTWAYS—8 FEET SEPARATED FROM THE ROADWAY BY A SAFETY FENCE SET BACK 2 FEET FROM THE ROADWAY KERB

GRADIENT OF THE BRIDGE DECK

THE BRIDGE DECK PROFILE IS PART OF A VERTICAL CURVE JOINING TANGENT LINES OF A GRADE 1 : 25 ON THE APPROACH EMBANKMENT

BALUSTRADES AND SAFETY FENCES

IN PANELS OF ANODISED ALUMINIUM

LIGHTING

ALUMINIUM STANDARDS SET IN THE LINE OF THE SAFETY FENCE AT 80-FOOT INTERVALS CARRYING LANTERNS MOUNTING THREE 80-WATT FLUORESCENT LIGHTS

SERVICES

FIVE 30-INCH DIAMETER WATER MAINS AND TWO 15-INCH DIAMETER GAS MAINS SLUNG UNDERNEATH THE DECK. LIGHTING, HIGH TENSION AND P.M.G. CABLES UNDER THE FOOTWAY SLABS

APPROXIMATE QUANTITIES

"CAMBIA" TYPE FOUNDATION PILES—20,960 LINEAL FEET
PORTLAND CEMENT CONCRETE—12,500 CUBIC YARDS
MILD STEEL REINFORCEMENT—2,000 TONS
HIGH TENSILE PRESTRESSING STEEL—325 TONS
ROADWAY SURFACING—8,600 SQUARE YARDS

The Approach Roads

KWINANA FREEWAY

FROM THE NARROWS TO CANNING BRIDGE—LENGTH OF DUAL CARRIAGEWAY = 3.4 MILES

SOUTHERN APPROACH ROADS

LENGTH = 1.3 MILES

NORTHERN APPROACH ROADS

LENGTH = 4 MILES
INCLUDING THE KWINANA FREEWAY FROM THE NARROWS TO CANNING BRIDGE, THE AREA OF THE APPROACH ROADS IS 235,000 SQUARE YARDS, WHICH IS THE EQUIVALENT OF APPROXIMATELY 17 MILES OF ROAD 22 FEET WIDE

RECLAMATION

DREDGING—4½ MILLION CUBIC YARDS
IMPORTED FILL—448,000 CUBIC YARDS

This Booklet . . .

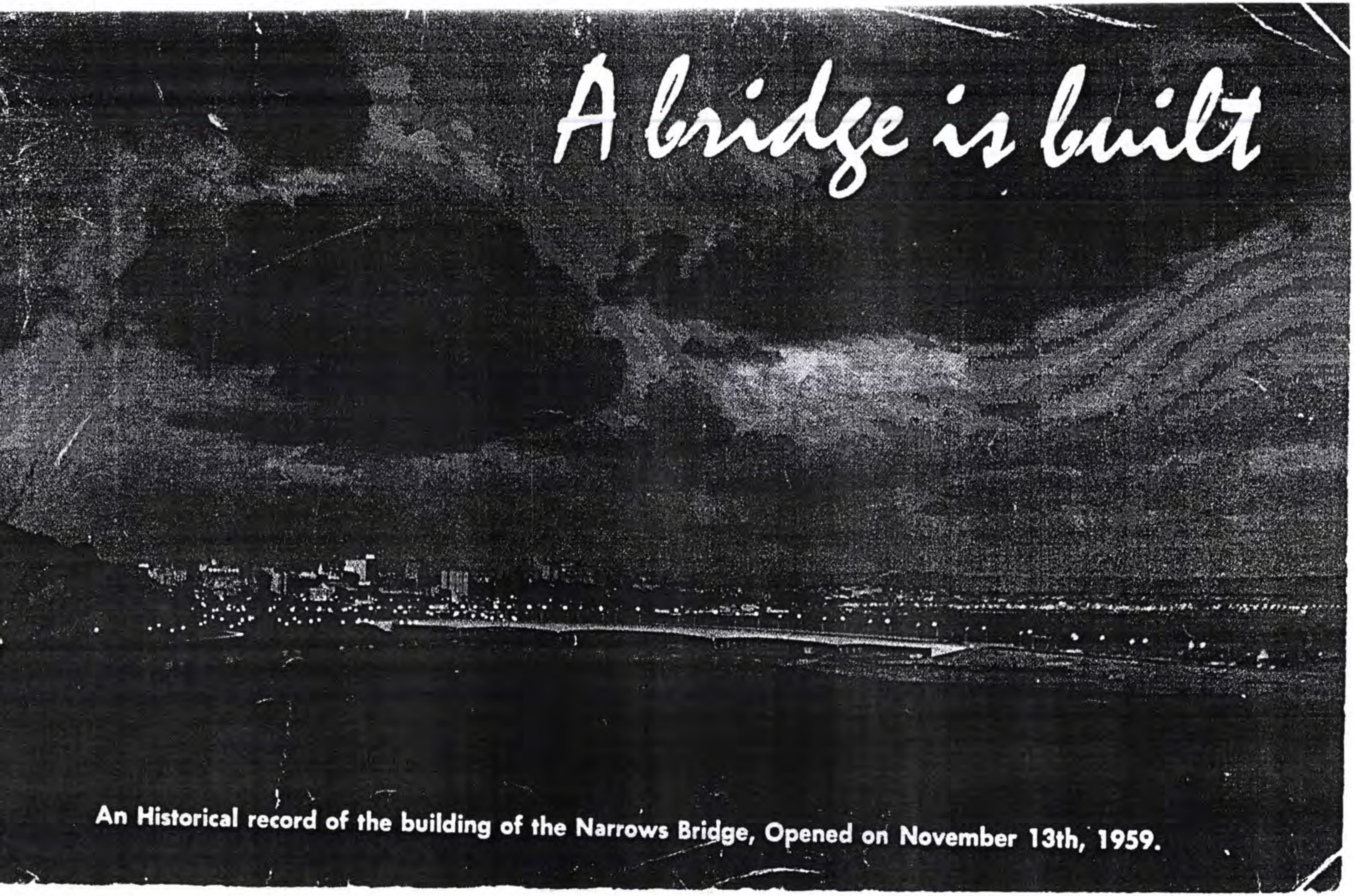
WAS PREPARED BY
THE MAIN ROADS DEPARTMENT
AND PRINTED BY AUTHORITY OF ALEX. B. DAVIES
GOVERNMENT PRINTING OFFICE
WESTERN AUSTRALIA

ATTACHMENT 7

A BRIDGE IS BUILT

An Historical Record of the Building of

The Narrows Bridge (November 1959)


A bridge is built
An Historical record of the building of the Narrows Bridge, Opened on November 13th, 1959.

COVER PICTURE: Now, with only minor "finishing touches needed, the bridge is almost ready for the opening ceremony. The lights have been switched on for the first time. With the city illuminations in the background it presents a sight of which Perth can justly be proud. This photograph was taken on the night of October 26th, 1959.

Praise the Bridge that carried you over — George Colman

A Necessary Step Forward

— Statement by the Rt. Hon. the Premier, Mr. D. Brand.

The Narrows Bridge is a necessary step forward in improving the capacity of the city's traffic arteries.

The present Causeway was another one of those steps, and we must take more of them if we are to keep abreast of expansion and progress.

Traffic censuses indicate that the Narrows Bridge will relieve peak-hour congestion on the Causeway for the time being. About half the Causeway traffic is expected to use the Narrows at this stage.

MR. BRAND

The new bridge will have other important effects. It can be expected to give impetus to development in South Perth. And, when planned new feeder routes are justified, it will provide uncluttered direct access to the city from Kwinana and beyond — via the Kwinana Freeway.

I congratulate the Narrows Bridge designers and contractors in producing a structure with aesthetic appeal. The bridge also had the advantage — being built of pre-stressed concrete — of requiring large quantities of local cement and aggregate, as well as other West Australian materials.

Here is a structure at least equal to anything of its kind in the world. It is a pointer to the progressive spirit with which the people of Western Australia will approach the problems and opportunities of the future.

— Statement by the Leader of the Opposition, the Hon. A. R. G. Hawke.

The new bridge is a great achievement and a big step forward in the safer distribution and control of vehicular traffic in Perth.

Everybody regretted the necessity of having to build a bridge across the Swan River at the Narrows. But an increasing need to promote safety on the roads was the factor which caused the Government — which it was my privilege to lead — to make the decision to have the bridge built.

MR. HAWKE

The then Minister for Main Roads (Mr. Tonkin), the Commissioner for Main Roads (Mr. Leach), the department's engineer (Mr. Godfrey) and other officers deserve much credit for their strong advocacy of the proposal to build a bridge across the Narrows.

All who have directly played a part in the construction of the bridge are deserving of the community's warmest thanks.

The building of the bridge is an important milestone in Western Australia's progress and expansion. It is indeed a wonderful structure.

However — and most important of all by far — is the added safety which it should give to the motoring public. The first duty of all motorists who use the bridge will be to promote road safety at all times — not only on the bridge roads but on all roads on which they travel.

WHY The Bridge Was Built

A LONG-HITTING professional golfer stood on the Perth side of the Narrows estimating the distance to the South Perth bank. Then he selected a two-wood, teed up a ball and gave it a mighty hit.

The ball sailed through air in a bridge-like arc and splashed in the edge of the water on the far bank.

All this took place in five seconds.

Being a whimsical sort of fellow, the golfer then drove at good speed to Mill Point via the Causeway to retrieve his ball.

The journey took 16 minutes.

That was in 1952. In September of that year a census showed that 3,600 vehicles an hour were passing over the Causeway during peak traffic periods.

In February, 1954, the figure had jumped to 4,250, and the tempers of motorists were becoming as worn as their brake linings. The rotary at the eastern end was operating near capacity and even minor traffic accidents caused serious traffic hold-ups to east and south-bound traffic.

It was estimated that "cloverleaf" treatment at each end of the Causeway to facilitate traffic flow would cost £500,000—a substantial part of the cost for a bridge across the Narrows.

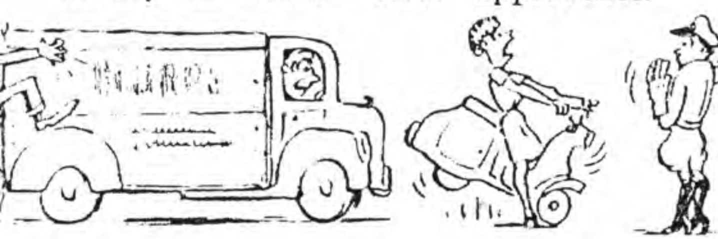
So the Main Roads Department proposed, in April, 1954, that a bridge be built across the Narrows. "Its construction is a matter of urgency," said Main Roads Commissioner J. Digby Leach.

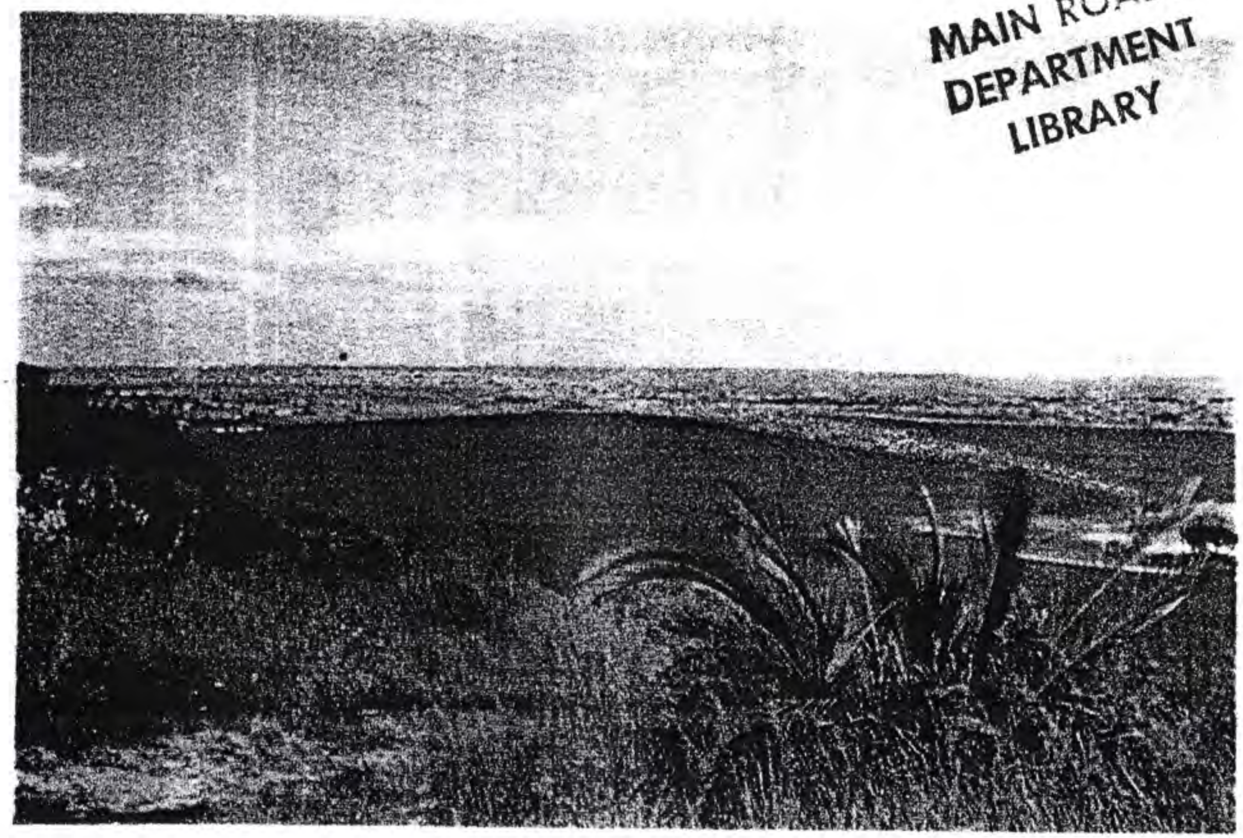
The Story In Pictures

No amount of words could describe the growth of the bridge as adequately as a series of pictures. And no picture can be as eloquent as one in colour.

The first in the series for this book was taken even before test boring began for the bridge's foundations, the last when the bridge was being "primped" for the opening ceremony.

Follow the pictures on the right hand page and watch the bridge grow from the ugly temporary trestling to the graceful structure that has enhanced the beauty of Perth's river approaches.





The Narrows before the first pile had been driven — Point Belches on the south shore, Point Lewis on the north. The first known reference to the need for a bridge across the Narrows was made by a private citizen in a letter to the editor of the Perth Inquirer in October, 1849.

The Decision is Made

THE LABOR Government acted quickly following the Main Roads Department recommendation that a bridge over the Narrows be constructed as soon as possible. Cabinet announced on August 10, 1954, that preliminary work would begin at once.

This would involve foundation testing by boring and an examination of the reclamation requirements for road approaches, said Works Minister Tonkin. He hoped that the bridge would be completed in four years. A tentative plan provided for four 11 ft. lanes, two 13 ft. lanes, 10 ft. footway on the upstream side and a 2ft. 3in. safetyway on the downstream side.

The length of the bridge would be 1308 ft. There would be nine spans of 132 ft. and two of 60 ft. Wisely, Mr. Tonkin pointed out that the finished design might depart wholly or in part from the department's tentative plan.

The type of structure would depend on the degree of firmness of the river bed.

The cost (including that of the preliminary work) he estimated would be £1,750,000.

All motorists living south of the river breathed a great sigh of relief and town planner Professor Gordon Stephenson said: "I'm glad to see a start is being made on the bridge—and the Narrows is the logical place." He forecast a northern approach road to the west of the city and extensive parking facilities on a reclaimed area of the river between the Narrows and the Esplanade.

A basic survey for the alignment of the bridge was completed within a few weeks of the announcement of its birth. Three drilling rigs bored to depths up to 200 ft. and revealed the presence of mud to a depth of 80 ft.

The dredge Stirling began operating on October 25, 1954, near Mill Point, where a large area needed to be reclaimed immediately for bridgehead and construction requirements.

On December 7, Mr. Tonkin announced that the Government proposed to call for alternative designs (accompanied by tenders). On January 26, 1955, he said that the Main Roads Department would be in fair competition with allcomers. Information about the proposed bridge would be sent all over the world to attract interest among contractors.

In May, 1955—when reclamation work was proceeding apace—Main Roads Department engineer E. W. Godfrey was sent overseas to talk with engineering authorities. "Consultation with experts is needed," Mr. Tonkin said.

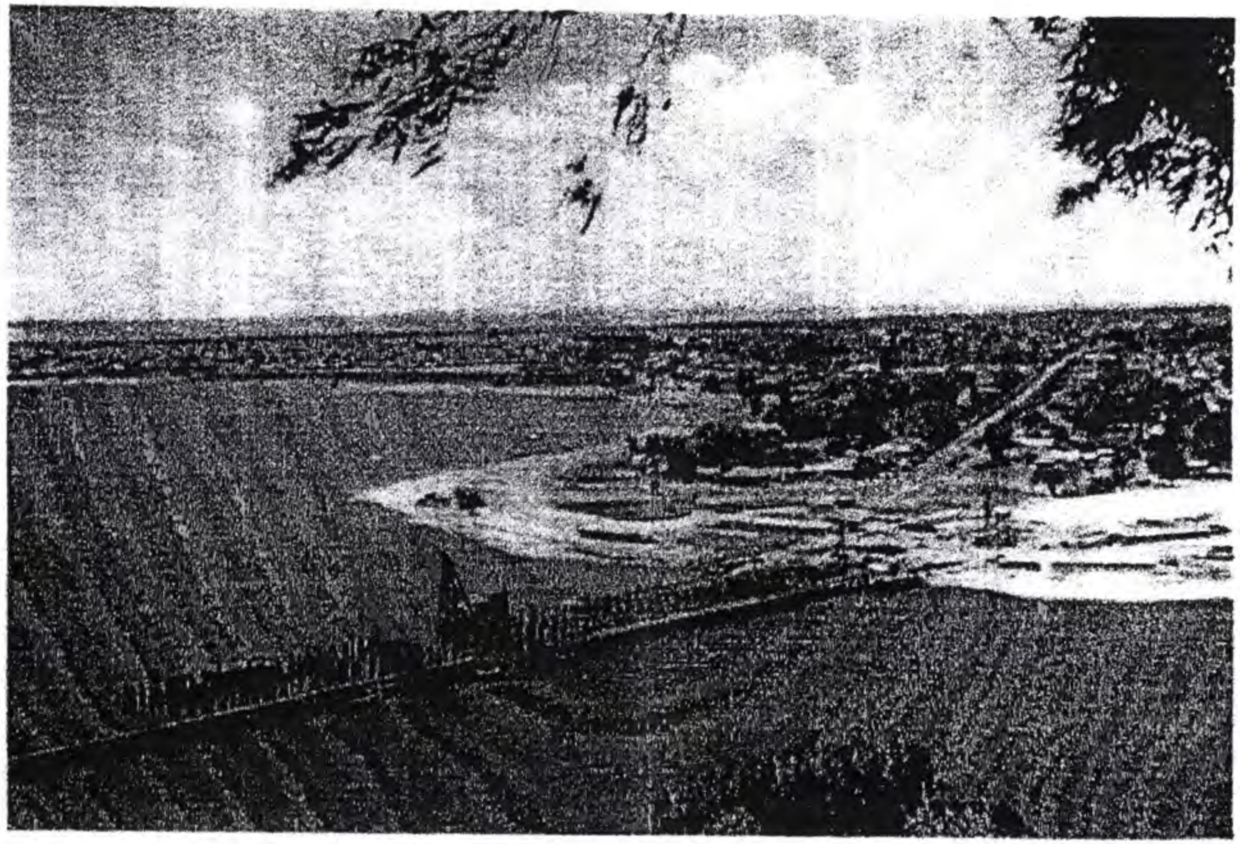
"It has now been decided that the vertical profile of the bridge is acceptable but we want to have the longest spans that the foundations will support.

Godfrey reported from London that a five-span structure with the centre span up to 350 ft. in length would be the best solution. The experts, he said, were against a suspension bridge.

The Premier then accepted a recommendation from the Main Roads Commissioner that Maunsell, Posford and Pavry, consulting engineers of London, be appointed to submit a report on the project. In December, 1955, Mr. C. S. Chettoe (recently retired chief bridge engineer to the U.K. Ministry of Transport) and Mr. R. W. Gray (partner in the firm of Sir William Holford) arrived in Perth on behalf of the consultants.

They presented a number of different designs and had numerous consultations with relevant Perth authorities.

In April a comprehensive report was submitted by Mr. E. M. Birkett (partner in the firm of Maunsell, Posford and Pavry). This report included details for a pre-stressed concrete structure in five



APRIL, 1957

The first stage in the building of the bridge — the provision of the temporary trestling which will later support the pre-cast beam sections assembled on the line of the bridge.

spans over a length of 1,100 ft. between abutments: a central span of 320 ft., two flanking spans of 230 ft., and a span of 160 ft. at each end.

The report included a design using steel girders and a concrete deck with spans identical with the pre-stressed concrete design.

The pre-stressed concrete design was considered the most pleasing of the two designs and was estimated to cost less than the steel design.

The concrete bridge provided for a six-lane carriageway 70 ft. wide (including two paths each 10 ft. wide).

The two outer lanes were to be 13 ft. wide, the inner two 11 ft. wide—the two central lanes to carry traffic in either direction, depending on the direction of the main traffic flow. The bridge was to rest on 168 Gambia piles—to be used for the first time in Australia. They were to be grouped in clusters of 32 in each of the two river piers (taking 64 piles), 20 in each of the two shore piers (40 piles) and 32 in each abutment (64).

The design had features in common with the much-admired Amstel Bridge, Amsterdam. The maintenance costs for a concrete bridge would be lower than that for a steel structure and more local material could be used. A concrete bridge would also be more pleasing artistically—an important factor because of the natural beauty of the bridge's setting.

The concrete design appealed to Cabinet, which approved the plan on May 1, 1956.

Detailed plans and specifications and contract documents were then prepared.

Tenders were called for in November, 1956, with the closing date February 1, 1957—and only tenders from contractors experienced in major bridge, concrete or maritime works were to be considered. Three tenders were received—one Australian, one English, one Danish.

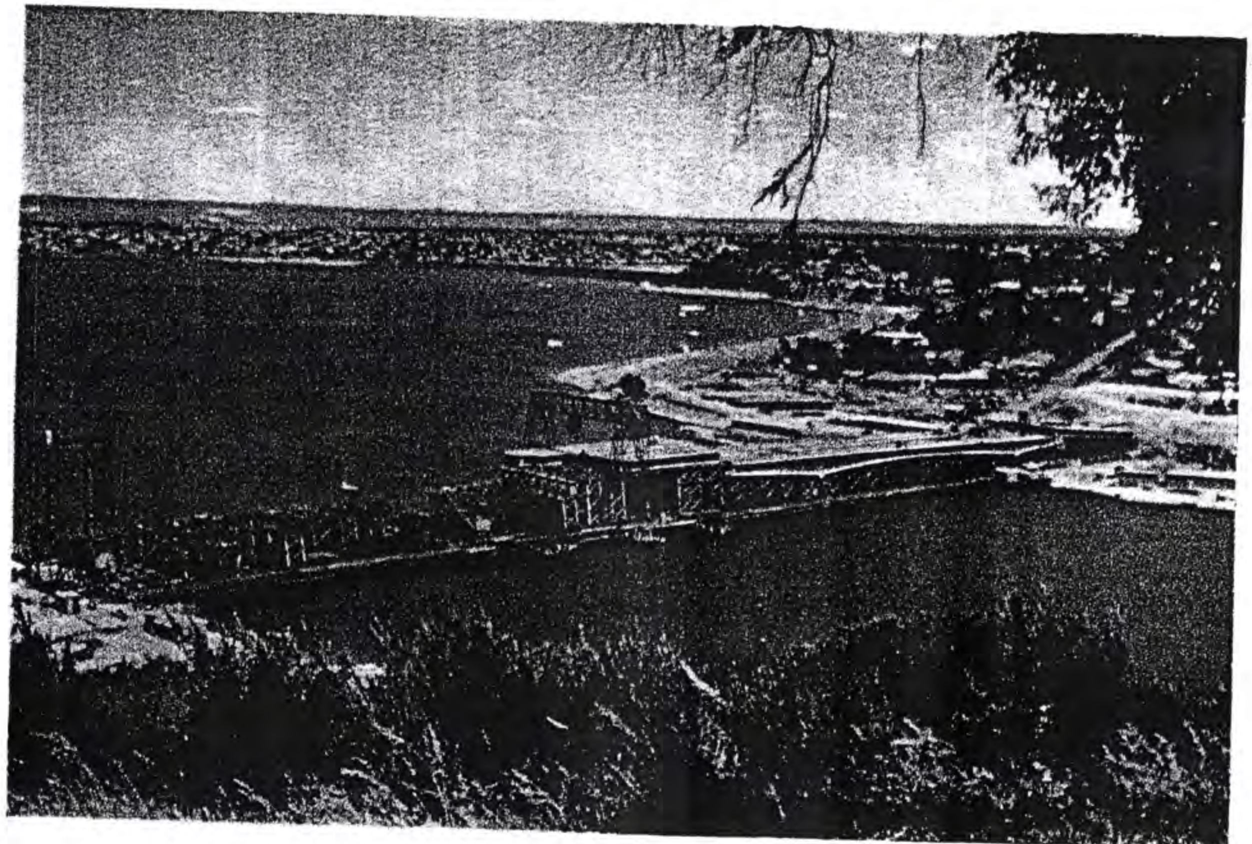
On March 12, 1957, it was announced that the contract had been let to the Danish firm, Christiani and Neilsen, in association with J. O. Clough and Son, Perth contractors, for a sum of £1,325,002/9/-. The construction deadline was two years from the date of signing the contract.

Christiani and Neilsen had already built pre-stressed concrete bridges in Siam, Holland, England, South Africa, Finland, Sweden and Brazil. The firm appointed Leif Ott-Nilsen to take charge of construction.

The Government retained Maunsell and Partners as consultants, who called in town planners and architects Sir William Holford and Partners. Sir William (a professor of town-planning at the London University and consulting architect for the City of London) was to landscape the northern approaches to the bridge working from a scale model in London.

Maunsell and Partners were to prepare all plans and specifications and supervise construction.

The first pile was driven on August 14, 1957, by a 10 ton, 20 ft. long hammer, and impatient Mounts Bay Road and Canning Highway motorists said, almost in chorus. "At last."



AUGUST, 1958

The south cantilever span has been erected at its correct level on the temporary staging. The south-suspended span is at a higher level to allow for subsequent stressing. The centre-suspended span — also erected at a higher level — is partly in position.

The Critics Have Their Say . . . . . .

NO-ONE in Perth opposed the building of a new bridge over the Swan—but no decisive step forward ever goes uncriticised.

The pens of those who loved the quiet waters of Mounts Bay dripped venom into the columns of the daily newspapers. For the bay was to be filled in and the fine arc of riverside plane trees was threatened.

The leader of the critics was prominent architect Harold Boas, who described the filling-in of the bay as "vandalism." He suggested a fly-over bridge to the abutment of King's Park. In a statement published in "The West Australian" on July 14, 1955, he deplored the lack of consideration of the public viewpoint.

He was supported in Parliament by Leader of the Opposition Sir Ross McLarty, who asked for a "second look" at the bridge plan. An editorial in "The West Australian" took the Government to task for not consulting Parliament or the public.

Premier A. R. Hawke argued that a northern link road to the bridge was one of the first matters considered by Professor Stephenson and Town Planning Commissioner J. A. Hepburn when they were producing the "Stephenson" report.

Works Minister Tonkin insisted that the water in the bay was frequently foul—that the river must flow, not lie stagnant. Also, he said, cars entering the city must have somewhere to park. And room was needed to sort out conflicting streams of traffic.

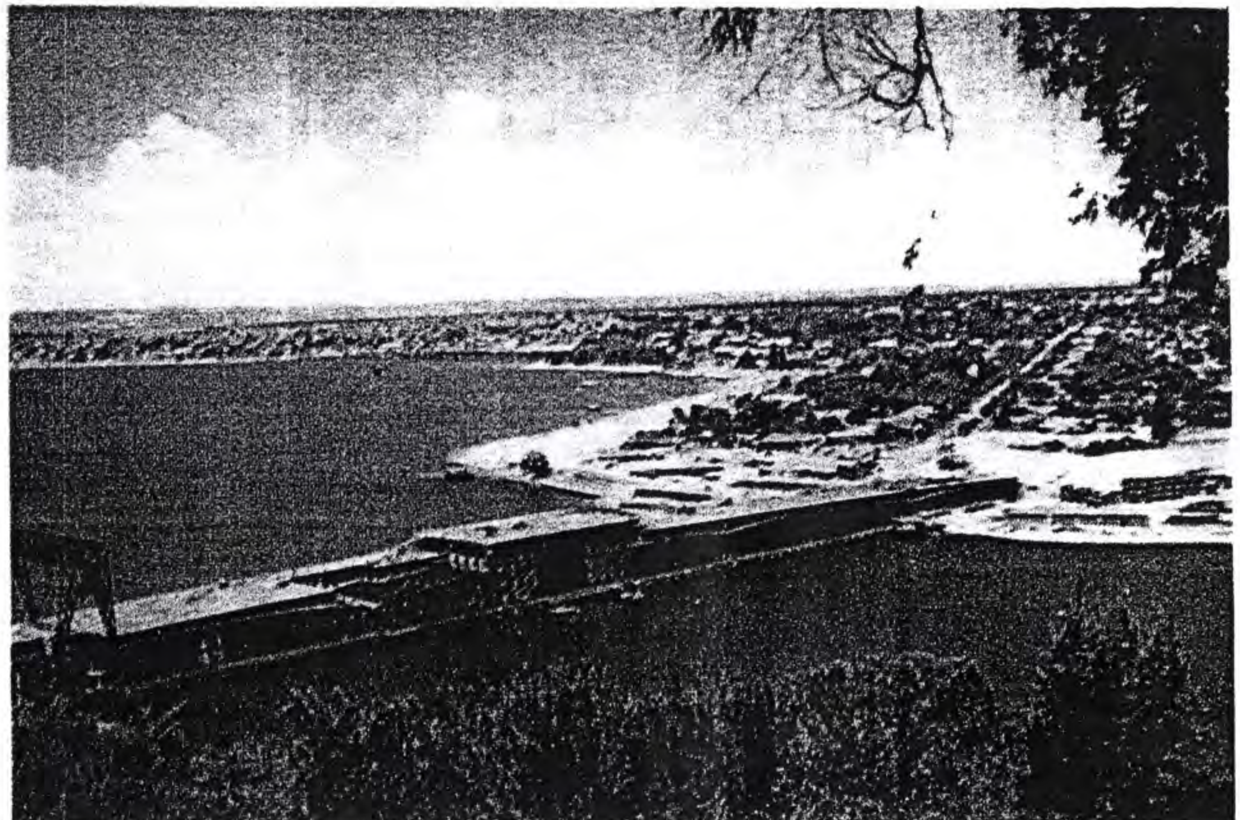
Aesthetics would be considered, he promised. Most of the trees would be preserved—they had, in fact, been plotted on a Main Roads Department plan.

"The Park route is out," he said, countering Boas's suggestion for a fly-over bridge. "Tunnelling would be expensive and steep grades make any other suggestion impracticable."

Controversy, too, raged on the other side of the Narrows. The old mill, it appeared, stood fair in the path of progress.

In May, 1957, it seemed to be reaching the end of its long life. Works Minister Tonkin told the W.A. Historical Society that the mill would be of value only if an attempt were made to restore it to look as it did when it was making flour a century earlier.

Tonkin was quick to point out that he was not threatening demolition—but it was not his duty as minister to allocate money to restore the old building. And obviously something needed to be done quickly if the mill was not to be swept away by progress.



FEBRUARY, 1959

The south-cantilever and south-suspended spans are now at the correct level (the south-suspended span has already been pre-stressed). Work is proceeding on the erection of beams in the north cantilever span.

He suggested that if the Historical Society could not find money to make badly-needed repairs, it might be desirable to remove the mill and the cottage and erect a plaque on a model of the mill.

A few weeks later National Park Board chairman H. E. Smith announced that the old mill was doomed. Serious cracks had been found in the mill structure and parts of the stonework were falling out.

"A considerable amount of money would be needed to repair the mill and if this were done its appearance would be altered," he said. "The Narrows Bridge approaches will leave the mill on a small triangular block, two sides of which will stand 12 ft. above the ground level of the reserve."

He suggested that a small replica be erected on a pedestal. Almost immediately a Perth businessman offered £50 to a fund to be set up to restore the mill. An appeal was launched by R. Cleaver, M.H.R., and A. Griffith, M.L.C. The money raised was to be offered to the South Perth Municipal Council, the Historical Society or any authority which might be able to persuade the Government to subscribe on a £1-for-£1 basis.

Meanwhile another Perth businessman—Bernard Hardwick, proprietor of Bernie's—offered to restore the mill and plant lawns and gardens in return for the right to build a coffee house for tourists.

The South Perth Council said it supported any move to save the mill—but not financially.

Then in August a private company ended the tilting at the windmill. Works Minister Tonkin accepted a proposal by the firm of H. L. Brisbane and Wunderlich to restore the mill in an old-world setting.

He recommended to the National Parks Board, which held the mill site in trust, that it lease the area to the company. Mr. H. L. Brisbane promised that the mill and cottage would be restored as near as possible to their original appearance.

He has kept his promise—the mill today looks exactly as it appeared in the 1850 water colour painting on which the restoration was based.

Banks on either side of the mill have been revetted with pre-cast concrete to protect the old building.

And in the grounds, relics of the State's early history have been tastefully displayed.

One more controversy remained before the finishing touches were put to the bridge.

Deputy-Premier Tonkin announced on February 10, 1959, that the name of the new bridge would be the Golden West Bridge, and the freeway to Canning Bridge the Golden West Freeway. Tonkin could not have dreamed that such a sweet-sounding name, with its connotation of sunshine and prosperity, would be criticised so vigorously. He was hopeful, in fact, that it would be a name that would go round the world to the advantage of the State.

But hundreds of people from taxi-drivers to academicians, waxed vitriolic in the columns of the newspapers. "A vulgar plagiarism on the Golden Gate of San Francisco," said the academician. "Very unoriginal," said the taxi-driver.

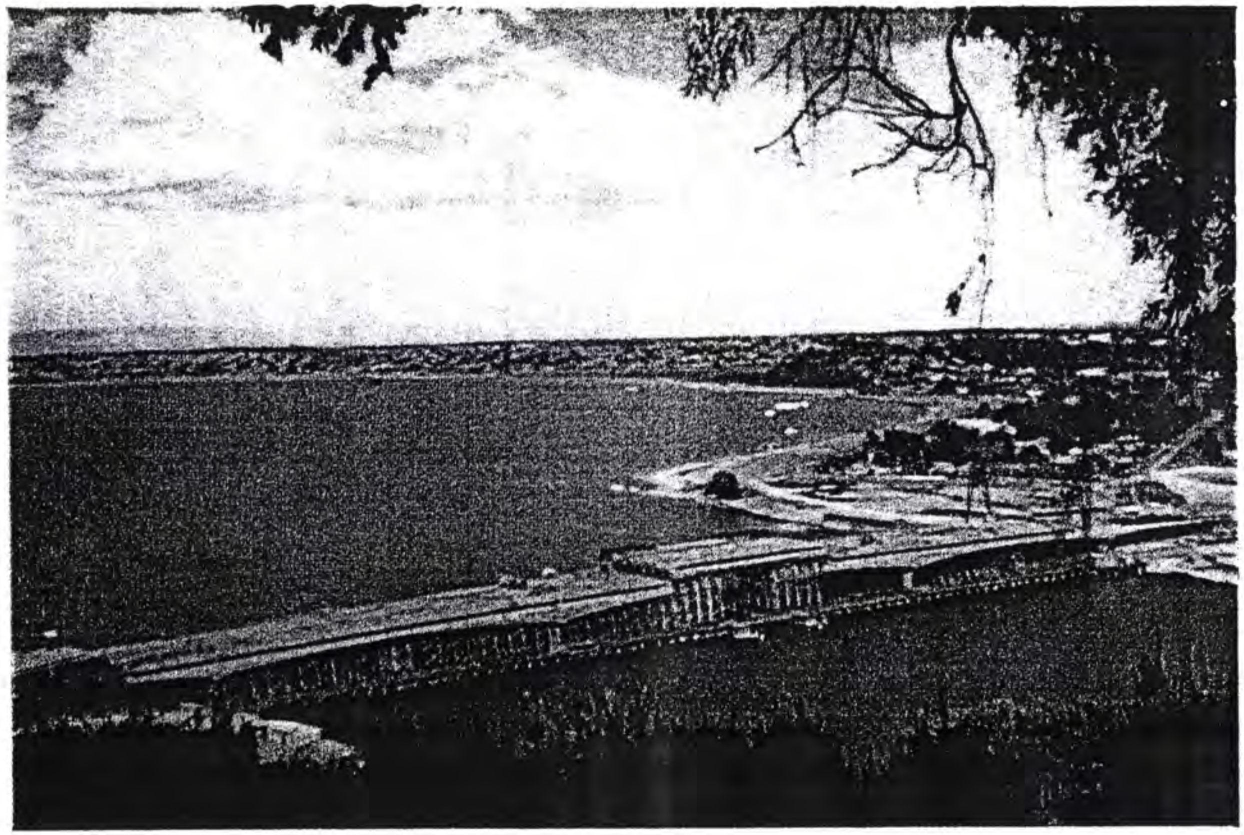
Other adjectives used by other people: awful, corny, detestable, high-falutin!

This criticism of one of the least important aspects of the bridge was even more lively than that made of the reclamation of the Mounts Bay.

Apart from Narrows Bridge, names suggested were Mill Point Bridge, Shenton Bridge, Swan Bridge—even Point Belches Bridge.

But soon it became obvious that the public greatly preferred the name by which the bridge had already become known: Narrows.

On April 21, the new L.C.P. Cabinet bowed to public opinion. Somewhat wistfully Tonkin, now deputy-leader of the opposition, said: "The Narrows Bridge seems to me more like the name given to a bridge over some little stream in the country. But what's in a name, as long as the structure is worthy?"



APRIL, 1959

The north-cantilever span is now erected at its correct level. But the centre-suspended span has not yet been lowered into position.

I WONDER WHY?---

YOU, like thousands of others, have watched the bridge slowly reaching across the Swan. You must have scratched your head and asked questions about the bridge which the man sitting next to you in the bus couldn't answer. The bridge is finished but we'll ask the questions again—and give you the answers.

Exactly who built the bridge?

Christiani and Nielsen (Australia), a limited company formed in Australia in which Christiani and Nielsen, Copenhagen, was associated with J. O. Clough and Son, Perth. The principal sub-contractors: H. L. Brisbane and Wunderlich Ltd. (aluminium balustrading); Wilson Gray and Co. Pty. Ltd. (dressed granite balustrading treatment); State Electricity Commission (lighting).

Why did it have to be a pre-stressed concrete girder type? What was wrong with a suspension bridge?

The type was selected as the best economically and aesthetically, having regard to the foundation conditions and the desire to preserve a deck line unobstructed by structural features above the deck line. A suspension bridge would have involved suspension cables and hangers above the deck line and would have created difficult anchorage problems.

Well, what is pre-cast, pre-stressed concrete?

The individual concrete deck units (weighing, in this bridge, up to 15 tons) were cast on the shore and assembled in position on temporary staging. They were made

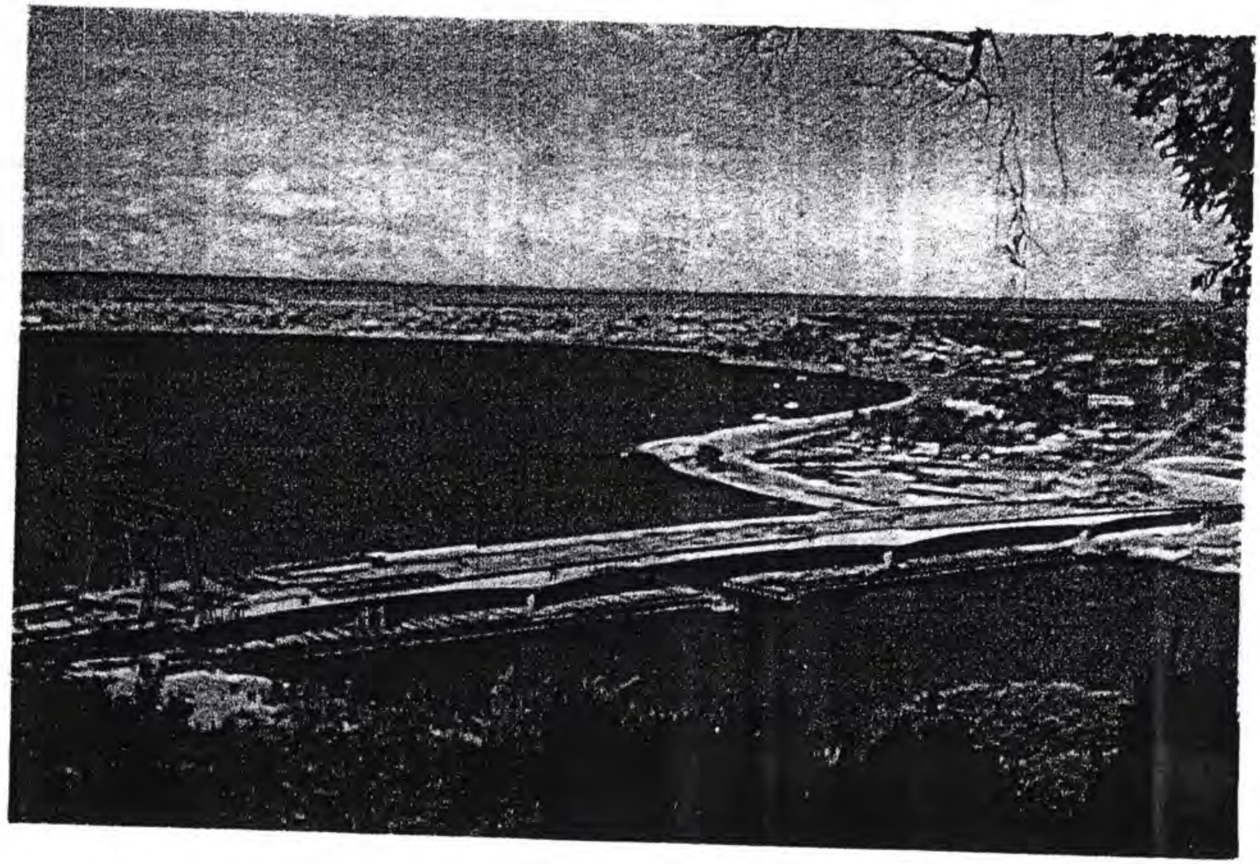
structurally continuous by strands of high tensile wire which, having been stretched to a pre-determined load by hydraulic jacks, were anchored off against concrete and anchor blocks. On the release of the load from the jacks the pull on the end anchorage imposed heavy compression forces in the assembled concrete units thus uniting them structurally and counteracting any tension forces which could occur due to the weight of the structure or any loading imposed on it.

What were all those pipes that floated in the river and seemed to be connected to the dredges?

They were the pipes delivering dredged material from the suction dredge to the area being reclaimed.

They say the bridge is built on Gambia piles—what are they?

A Gambia pile is a hollow steel cylinder (in this bridge 31 in. in diameter) the bottom 15 ft. of which is filled with concrete. The driving hammer (weighing 10 tons) falls inside the casing on to the concrete at the bottom. As driving proceeds the casing is extended by welding



JUNE, 1959

The centre-suspended span has been stressed and lowered into position. Erection of the north-suspended span is proceeding.

and after a satisfactory resistance to driving is reached the hammer is withdrawn, and the casing filled with concrete in which steel rods are embedded. Should the steel casing subsequently corrode the enclosed reinforced concrete acts as a normal reinforced concrete pile. Piles were driven to a depth as great as 110 ft.

Why did they build some parts of the bridge "up in the air" then lower them into place?

The bridge was built as five individual sections; that is, each of two main cantilevers were supported on one river and one shore pier, with a central suspended span and two end-suspended spans. Each of these five sections was individually pre-stressed. This pre-stressing involved the use of hydraulic jacks of a length extending beyond the sections. The two main cantilever sections could be stressed at their correct level but the three suspended spans had to be temporarily erected at a higher level to allow the stressing to be done. After anchoring off, the suspended spans were lowered to their correct positions.

The bridge is fixed at the northern end and moves on rollers at the southern end—so providing for expansion and contraction due to temperature changes. The total estimated movement (lengthening or shortening) is $3\frac{3}{4}$ in.

How did they join all the different concrete sections together?

The structural union was made by the system of pre-stressing already described. The five individual sections mentioned in the previous paragraph were joined by high tensile continuity cables passing through heavy concrete blocks in the adjoining sections.

How did they get the water pipes and power cables through the concrete?

The water pipes were slung from the flanges of the deck beams and were placed in position as the erection of the beams proceeded. The power cables were located underneath the footway slabs.

If they say the bed of the river is soft at the Narrows, won't it sink in the mud after a while?

The Gambia piles which support the bridge were driven through the river mud into the underlying sand layers—and driven to a pre-determined "set" which enabled their resistance to sinking under a load to be determined. In addition, actual loading tests on piles in different groups were made to twice the load they will be called upon to carry. These tests were satisfactory.

Why did they take so long?

The original contract date for completion was April, 1959. Unforeseen foundation difficulties required an extension of time but the contractors handled the problem with speed and efficiency.

Will the bridge be properly lit up at night?

Lighting standards are placed only 80 ft. apart. That means there are 16 on each side of the bridge making a total of 32. Each standard mounts three 80-watt fluorescent lights.

How much did it cost?

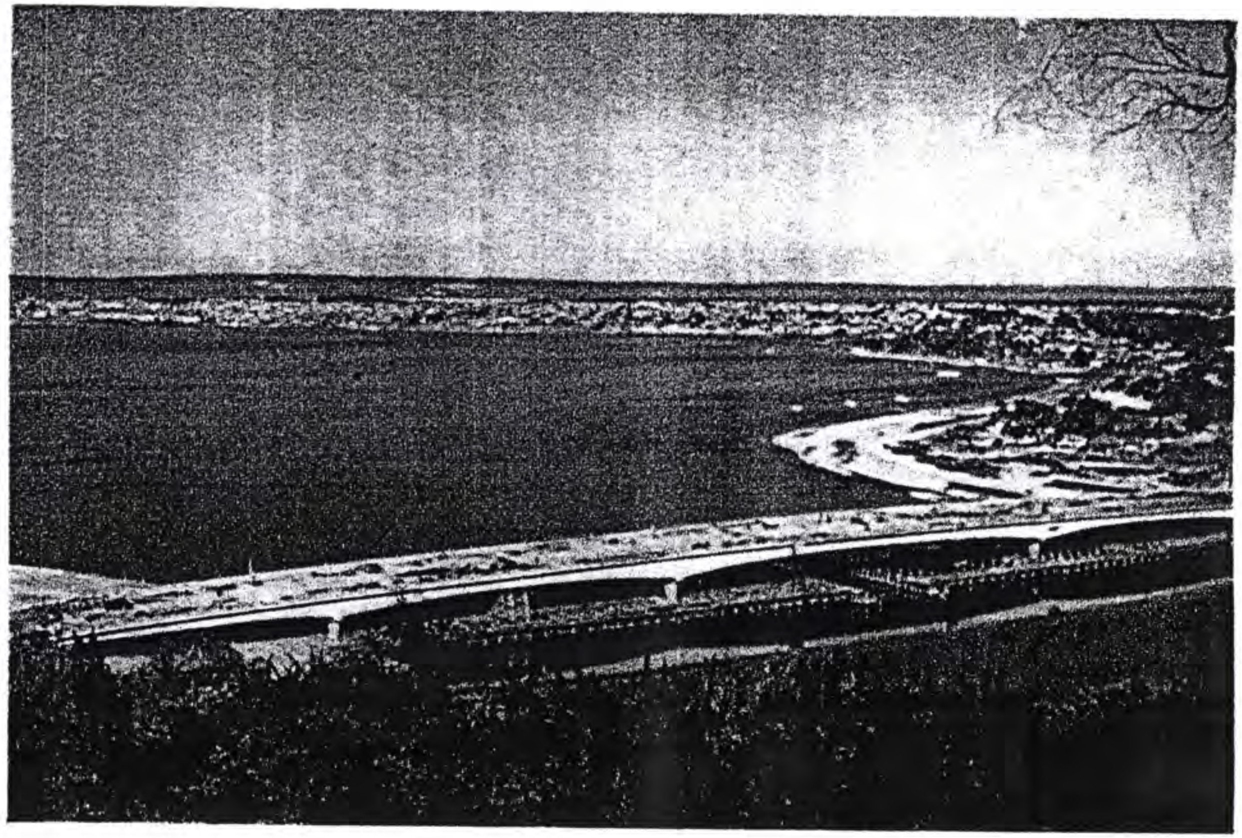
The contract price for the bridge itself was £1,325,002/9/-. Because of extras due to foundation difficulties on the north side this figure was exceeded to some extent. The all-up cost of the bridge and approaches exceeded £3,000,000.

And where did the money come from?

More than half the cost of the bridge itself came from vehicle license fees collected in the metropolitan area. The balance was provided from petrol tax funds. The northern and southern approaches were financed entirely by petrol tax funds.

Why were they certain that the bridge would meet in the middle?

Accurate surveys determined the distance across the river and during construction care was taken in the placing of the piers and the construction and erection of the individual deck units to see that the distances as set out by the engineers on the job conformed with the original survey distances and constructional details.



AUGUST, 1959

The north-suspended span has now been stressed and has been lowered into position. The bridge is now taking positive shape.

REALITY OF THE APPROACHES

The bridge was designed for a traffic intensity during peak periods of 6,000 vehicles and 6,000 hurrying drivers an hour. This meant that the capacity of the approaches had to match the capacity of the bridge—segregation of the major traffic stream was necessary.

For the northern approaches this involved the reclamation of about 60 acres of Perth water (from a total of 890 acres). Many of the citizens of Perth viewed the reclamation with a jaundiced eye but there was no practicable alternative.

The loops for the approaches demanded certain radii for certain speeds. At speeds of 25 to 30 m.p.h., the radius of each loop was estimated at 130 feet. Only reclamation could have provided the necessary room clear of the bluff of Mt. Eliza and made grade separation (some people say "fly-unders" and "fly-overs") possible.

The first stage of grade separation—that near the bridge—has been completed. Further separation will be necessary when the western switch road is built.

Reclamation has also made possible the large parking areas near, but thankfully outside, the city.

The ground conditions on the northern approaches were a dredge master's nightmare. The shallow section of Mounts Bay was reclaimed to a depth of 70 feet of mud. Pumped "fill" was placed behind a marginal line of sand and shell placed in turn by grab and suction dredges from materials stockpiled earlier.

Dredging to reclaim this area was begun in October, 1954, and given urgent priority. An additional dredge was soon found to be necessary. The huge quantity of 1,750,000 cubic yards of material was pumped over a period of 42 months to September, 1958, when dredging finished.

This astonishing figure does not include the pumping of another 1,000,000 cubic yards where the double-handling or removal of mud waves displaced by the fill was involved.

The siting of the bridge has also made feasible an adequate, modern roadway to Canning Bridge. This roadway was located largely on land reclaimed from the river by suction dredging about 1,500,000 cubic yards of sand and shell from the river bed of Melville Water.

From the bridge to Canning Highway the roadway was fenced on both sides, with three "slip-off" roads leading to the road system of South Perth and one permanent and another temporary "slip-on" road. The temporary road will be eliminated when grade separation becomes necessary at the Canning Bridge end.

Access to the popular river beach frontage along Melville Water had to be preserved. Also, it was necessary to provide safe crossing of the high-speed section of the highway.

Five concrete bridges with helical ramp approaches were the answer.

WATER UNDER THE BRIDGE

GEORGE SHENTON, brother of William who built the old mill, probably would have been glad of a bridge across the Narrows when he was attacked by natives on April 24, 1834. But his opinion—if he had one—on a bridge has not been recorded.

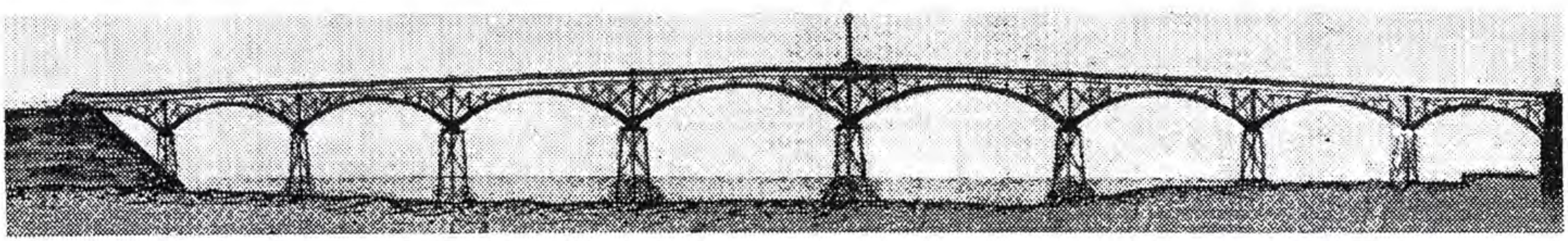
The earliest mention in the Press of a bridge over the Swan at the Narrows was made in the "Inquirer" in October, 1849. A person who signed himself Viator, pressed for a bridge despite the "unfavourable state of the colonial exchequer." The somewhat critical Viator wanted the erection of the bridge "put under proper professional control so that our colony may be no longer reproached for its mushroom and defective growth."

Viator went unheard.

In July, 1895, a design for a bridge over the Narrows was made by a civil engineer named Alex R. Terry and was discovered recently among the papers of the late H. E. Victor, W.A.'s first engineer-in-chief. But it is doubtful if the plan ever got beyond the drawing board.

Perth might still have had a bridge at the turn of the century if a plan first presented to the Legislative Assembly in 1899 had been adopted. But it was vigorously opposed because the estimated cost—£13,000—was thought to be too great.

The first known design for a bridge across the Narrows. It was prepared by civil engineer Alex R. Terry in July, 1895 — but the project got no further than the drawing board.



Gasps of dismay from the Parliament House in 1899 are almost audible today when the cost is mentioned in the musty pages of Hansard. The plan was suggested in December, 1899, and led to three proposals for a bridge. Premier John Forrest set the tone for the debate on the bridge when he said a ferry service would do just as well and would not interfere with river navigation. But he grudgingly agreed to have tentative estimates drawn up.

Canning member (later Premier) Frank Wilson had moved a motion that the Government give early consideration to a bridge. He could have been looking ahead to the days of traffic jams when he pointed out that the only way to reach South Perth was by ferry "or the long route over the Causeway." He claimed that the Narrows bridge would make South Perth only seven to ten minutes' travelling time from the city.

Railways Commissioner F. H. Piesse thought the bridge would be a mistake. It would, he said, "obstruct navigation and detract from the appearance of the river." He pointed out that the Government planned to deepen much of the river to encourage river traffic.

Plans and estimates for three different types of bridges were finally tabled in the Assembly in 1901. Prepared by roads and bridges engineer C. S. R. Palmer, each plan allowed for two tram tracks on a 41 ft. wide roadway over the bridge.

But little consideration was given to aesthetic factors.

The 900 ft. long bridge was to have had timber piles and embankments would have carried roads and tram lines to each end. There would have been two navigation ways under the bridge, each 50 ft. wide. Swinging centre spans to allow large vessels into Perth water would have brought the cost of the bridge to £25,000, if they had been built of timber, or £50,000 if built of steel.

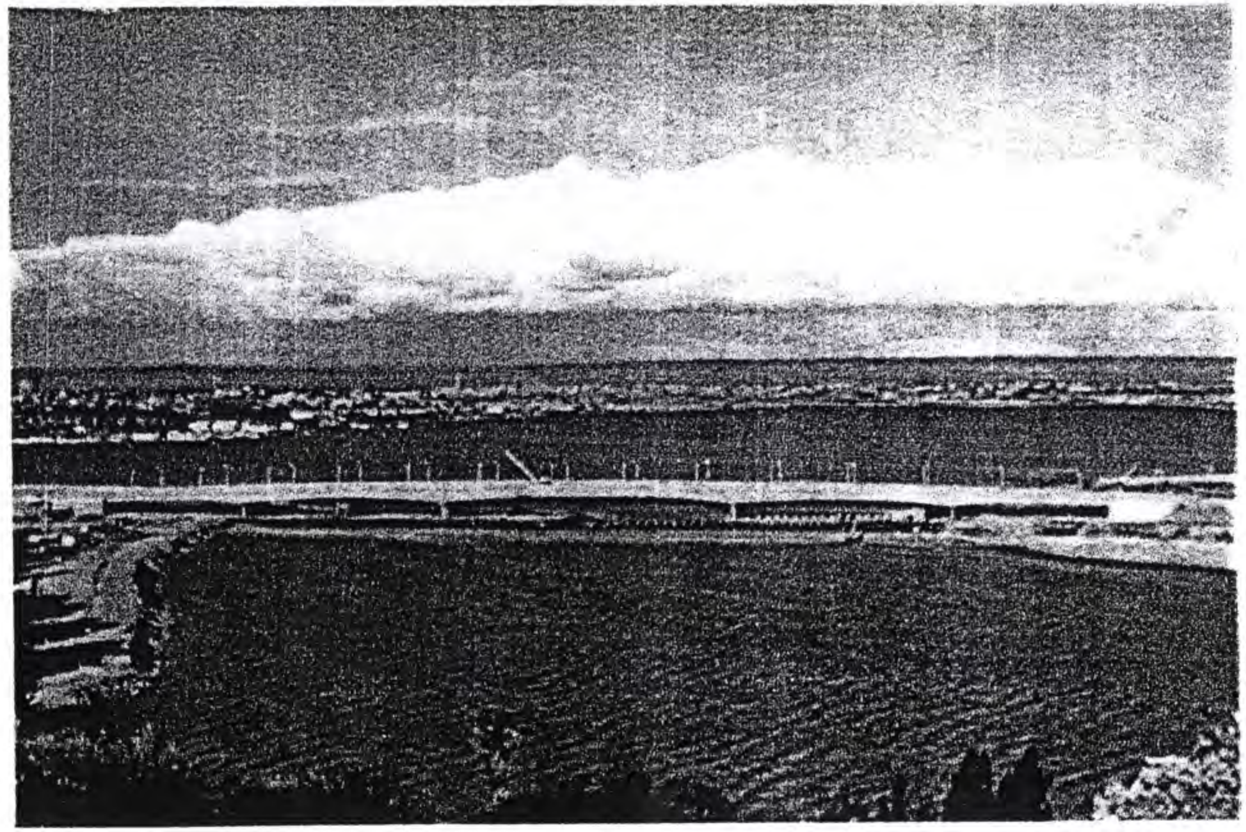
Palmer's report was tabled in the House in July, 1901. Remembering perhaps Sir John's almost bored observation two years earlier that he could see little need for the bridge, no member even bothered to comment on the document.

A bridge over the Narrows got a mention again in a report of the Metropolitan Town Planning Commission (well known architect Harold Boas was chairman) tabled in December, 1930.

The report said that the Narrows afforded a natural and necessary opportunity for linking both sides of the Swan. However, objections were raised from the aesthetic point of view and the possibility of building a tunnel was discussed.

But the commission made no final recommendation.

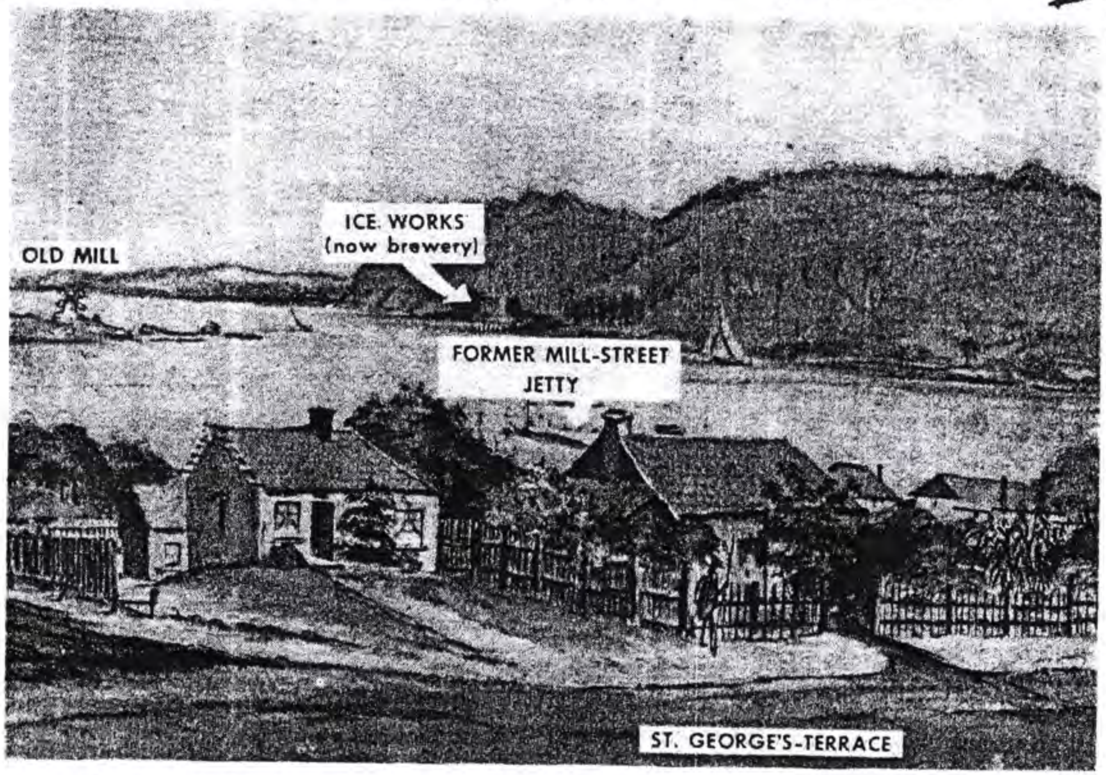
And so water was allowed to run under the bridge that wasn't there until the move to build the present structure was made.



SEPTEMBER, 1959

Now nearing completion — this view looks north-east towards Barrack Street. Light standards are in position and the temporary wooden structure has been partly removed.

The Old Rustic Mill By The Bridge...



Reproduction of the only known painting depicting the Old Mill with sails. Also featured: the old Mill Street jetty; an iceworks (now Swan Brewery); cottages in St. George's Terrace and other forgotten scenes of old Perth. The artist was A. Taylor. The picture was painted in 1850 from the window of an old shop then next to the A.M.P. Building. The original was supplied to the Perth Art Gallery by Mrs. Evelyn Coombe of Singapore.

ENGINEER William Kernot Shenton, aged 26 and a bachelor, arrived in the colony in the ship Lotus in October, 1829.

He was under a 10-year indenture to Colonel Peter Augustus Lautour to saw timber and grind flour for Swan River settlers. According to the indenture, Lautour was to advance Shenton £325 for the purchase of mill parts and machinery in England. Shenton was to go to the colony where he would claim from the Government 4,320 acres of land. As soon as that had been arranged, Shenton would build the mill and transfer it and portion of the land to Lautour. Shenton was to receive a salary and a percentage of profits in return for managing the felling of trees and exporting the timber.

Shenton was to be advanced money for tillage implements, seeds and stock with which to begin development of the allotment. Lautour would also build a cottage for Shenton, another for the mill foreman.

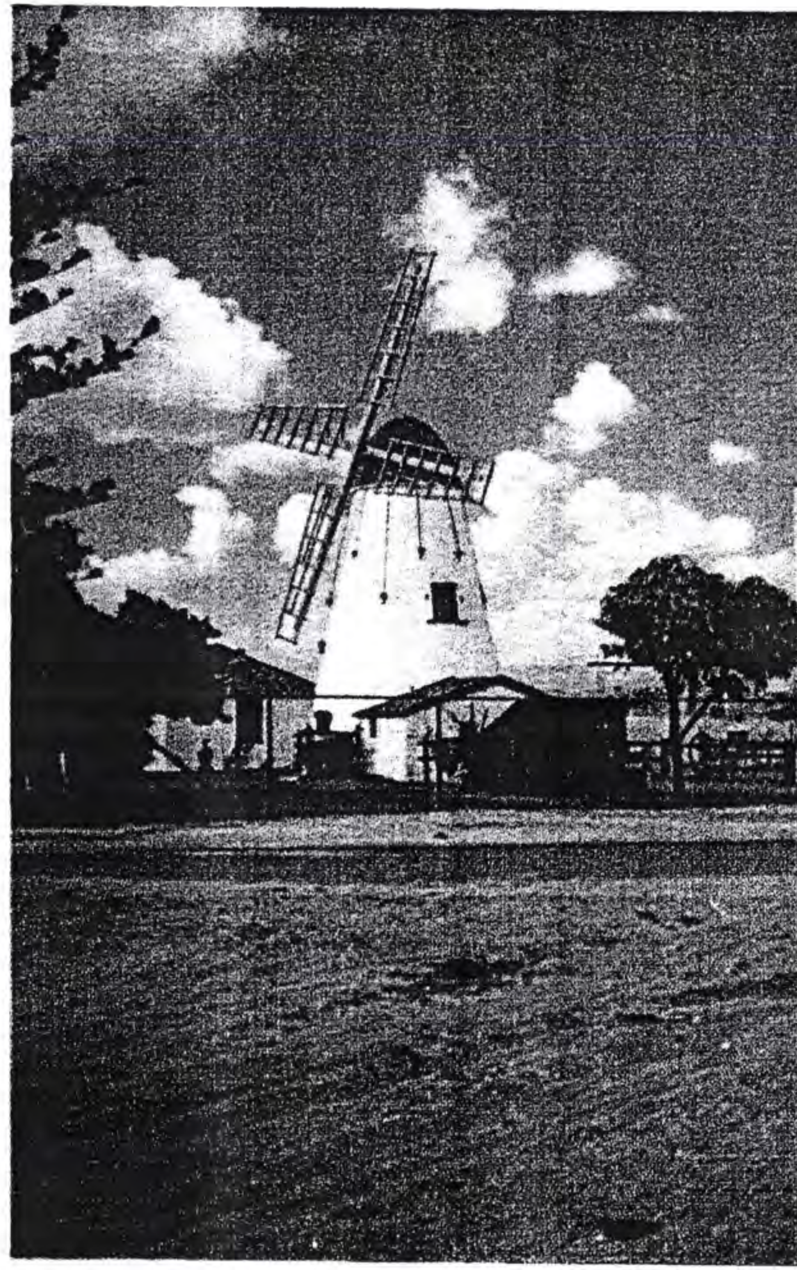
Shenton arrived in the colony with a sawmill and other property worth £852. He built the mill at South Perth and was given permission to select 11,360 acres of land, most of it in the Leschenault area near Bunbury, some near the Helena River at Guildford.

Despite the interest he had shown in the colony, Lautour never left London — though he planned an ambitious immigration scheme for 100,000 acres of land at Leschenault which came to nought.

Within a year the Shenton-Lautour organisation broke up. Shenton carried on as the miller and the mill came to be known as Shenton's Mill.

Shenton built his first mill at Point Belches (the point was named after Peter Belches, third lieutenant of Captain Stirling's ship H.M.S. Success) in 1833.

It was not a success and was burnt down—whether by accident or hostile natives is not known. Not one to give in easily, Shenton built a second mill, the foundation stone of which was laid by Governor James Stirling on October 19, 1835. This is the mill that stands today.



Designed by Shenton, it was built by Lockyer and Son.

In the 1830's Point Belches was covered by thick scrub. On the tip of the point was a natural lagoon which came to be called Miller's Pool. Seventy yards across and up to 12 ft. deep, it was a favourite picnic spot until 1862. In that year, floodwaters deposited hundred of tons of silt in the pool and turned it into a swamp. It remained as a swamp until 1935, when it was filled in for health reasons.

In the 1830's natives, resentful of the intrusion on their hunting and fishing grounds, were troublesome to settlers. The mill site was badly situated as far as attack by natives was concerned because marauders could approach unseen from the direction of Canning River. In April, 1834, natives made an attack on the first of Shenton's two mills in search of flour and other stores.

William Shenton's cousin, George, was in charge at the time—he was, in fact, the only man south of the river. He locked himself in the mill and kept the dozen or so natives at bay for two hours. Finally the door was forced and Shenton pushed on to his back. While one native threatened him with a spear, the rest of the raiding party looted the mill of its stores and flour.

When the last of the natives had disappeared, Shenton—greatly surprised that he was still alive—shouted for help across the Narrows. Troops of the 21st Regulars crossed the river and scoured the point but the natives had escaped. Eventually five of the miscreants were caught near the Murray River and the ringleaders flogged.

In 1841 Shenton sold the mill and married. In 1842, he took his bride aboard the schooner Devonshire to sail to Australind. The ship was lost with all hands in a storm.

Afterwards the mill passed through the hands of several owners but never seemed to be a sound proposition —possibly because of the difficulty of transporting corn and flour across the Narrows.

The old mill finished operating as a flour mill in 1859. But additions were made—including a verandah in the 1870's—and it was used for various purposes until soon after the turn of the century.

Then it began half-a-century of decay. From time to time, letters appeared in the Press advocating restoration of the old building. But good intentions were never matched by hard cash. True, in 1929 a plaque was fixed to the crumbling walls detailing the mill's history. And in 1935 the mill cottage was re-tiled with she-oak shingles.

In 1955 there was a flurry of interest when the State Gardens Board asked the Public Works Department for a quote for repair work. But the matter lapsed when nobody could decide exactly how the mill looked in the 1830's and to what form it should be restored.

But they were the bad old days. Today the mill is an impressive memorial to one of our most industrious pioneers.

So well has the work been done that visitors would scarcely be surprised if Shenton, dusting flour from his hands, stepped from the door.

BEAUTY GIVES WAY TO PROGRESS

This view taken before the reclamation shows the City overlooking the placid waters of Mounts Bay. Many will miss this beautiful and restful scene.

THE MEN WHO BUILT IT

DR. REID CHRISTIANI

MR. ALEX CHRISTIANI

MR. W. H. CLOUGH

MR. E. W. C. GODFREY

MR. J. DIGBY LEACH

Dr. Reid Christiani: Established, with Captain Aage Nielsen, the firm of Christiani and Nielsen in 1904. The company has developed into a world-wide organisation with approximately 40 subsidiary companies and branches. After the death of Captain Nielsen, the firm was carried on by Dr. Christiani and his son, Mr. Alex Christiani. In 1958 the firm was incorporated as a limited company with Dr. Reid Christiani as chairman of the board of directors.

Mr. Alex Christiani: Son of Dr. Reid Christiani and now managing-director of the company. Christiani and Nielsen, of Copenhagen, Denmark, were the principal contractors for the bridge and were responsible for the overall planning of the method of construction of the bridge according to plans prepared by the consultants.

Mr. Leifoh Nilsen: The engineer representing Christiani and Nielsen on the job and responsible throughout for detailed planning of the methods of construction. Manager of Christiani and Nielsen (Australia), a partnership formed with the firm of Clough Construction Pty. Ltd. to build the bridge.

Mr. W. H. Clough: With Mr. J. O. Clough the joint proprietor of Clough Construction Pty. Ltd., Assistant-manager of Christiani and Nielsen (Australia). A graduate of the University in W.A. in 1947, he was in charge of the production and driving of the Gambia piles forming the foundation of the bridge.

Mr. E. W. C. Godfrey was the Bridge Engineer of the Main Roads Department during the preliminary stages of investigation.

He is a graduate in Engineering of the Melbourne University, and a member of the Institution of Engineers, Australia.

After it had been established that an economic design was inadequate aesthetically, Mr. Godfrey was commissioned to go overseas and examine and report on modern bridge types in Europe and the United States. It was necessary also for Mr. Godfrey to make recommendations regarding suitable engineering consultants for the purpose of design, calling of tenders, and field supervision.

During the currency of the contract, Mr. Godfrey has been Liaison Engineer between the Consultants and the Main Roads Department.

Mr. J. Digby Leach is Commissioner of Main Roads in this State.

He is a graduate in engineering of the University of Western Australia, and a Member and Councillor of the Institution of Engineers, Australia.

It was Mr. Leach's responsibility to ensure that the aesthetics of the magnificent site were adequately catered for, and that the Government was properly advised regarding general planning and design and construction of both the bridge and the north and south approaches. It was his responsibility also to sign the contract on behalf of the Government for an amount of £1,325,000 to negotiate financial arrangements with the Contractor, and to approve of all progress payments. Throughout the period of construction he maintained close contact with the varying phases of the work by regular reports from his staff and by personal inspections.

Mr. T. G. Bingham: Resident engineer for the consultants, G. Maunsell and partners. A graduate of the University of London, his job was administration of the contract and supervision of structural work to see that the bridge was built according to drawings and specifications.

The compilation of this record would not have been possible without the co-operation and assistance of the Main Roads Department, the State Electricity Commission and the Bridge builders. To those concerned the publishers extend their sincere appreciation.

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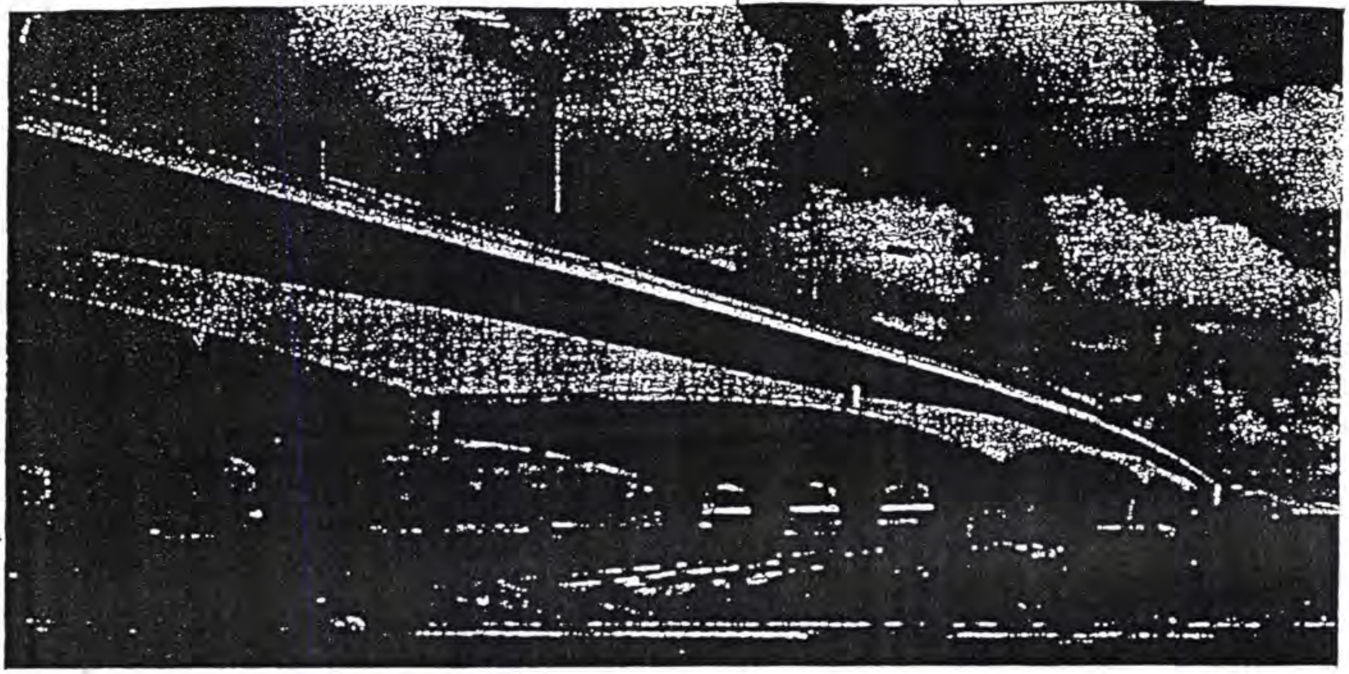
ATTACHMENT 8

NARROWS BRIDGE, PERTH

Roads and Road Construction (December 1959) pp 364 - 367



NARROWS BRIDGE, PERTH

Narrows Bridge, Perth, in Western Australia, which is the largest precast prestressed concrete continuous beam bridge at present in existence, was opened on November 13 last by the Governor of Western Australia, Sir Charles Gairdner, K.C.M.G., K.C.V.O., C.B., C.B.E.

Introduction

The main part of the City of Perth stands on the north bank of the Swan River some 10 miles above Fremantle, but extensive suburban development has taken place on the south bank and is continuing. Hitherto one bridge linked the two parts of the City. This had become inadequate and the need for a second bridge was acute.

The Swan River Narrows was an obvious choice of site as here the width is between 700 and 800 ft., whereas elsewhere large lake-like reaches known as Perth Water and Melville Water would require an extremely expensive bridging operation. The site is suitable also from the point of view of traffic flow requirements and is a scene of great natural beauty, being flanked by a wooded hill known as Mount Eliza, which is reserved as a public park—King's Park.

When the decision to build a bridge was taken the engineers of the Main Roads Department prepared a sound and economical design, but it was felt that the beauty of the site and the prominence in the scene which the bridge would possess demanded a design ,which would enhance its natural setting and impede as little as possible the fine views presented by nature and the city itself. Accordingly, in 1955, Mr. E. W. Godfrey, at that time the bridge engineer of the Main Roads Department, was commissioned to visit Europe to discuss the problem with leading bridge designers and to select a firm of consulting engineers for appointment.

On his recommendation G. Maunsell and Partners were appointed consulting engineers, and Mr. C. S. Chettoe together with Mr. Richard Gray, a partner of William Holford & Partners, visited Perth in December, 1955, to consider the problem on the spot, to advise on the bridge loading to be adopted and to collect all the local information necessary for the development of the design.

A report was prepared by the consulting engineers and presented in April, 1956. The report covered two designs—one in prestressed concrete, the other in steel—and recommended the adoption of the former, principally on the grounds of cheaper first cost and lower maintenance charges. Tenders were called in February, 1957, and that received from Christiani & Nielsen in conjunction with J. O. Clough and Son Pty. Ltd. was the lowest and was accepted.

Construction commenced in April, 1957. At the start of construction, Mr. Birkett, a partner of G. Maunsell & Partners, took up residence in Australia in order to give closer supervision than would have been possible from the consultants London office. During the deck prestressing operations, Mr. H. E. Lewis, an engineer on Mr. Gifford's staff, was resident on site in order to give detailed supervision and instruction in the new form of the Gifford-Udall system which had been developed for the project.

Throughout the contract Mr. E. W. Godfrey, who had retired from his position as bridge engineer to the Department, acted as liaison officer between the Commissioner and the consulting engineers.

General Description

The park-like approaches and the background of the King's Park escarpment have determined the visual character of the bridge. The unbroken flow of the road from one side of the river to the other makes a strong horizontal line, to which Mount Eliza provides a perfect natural foil. The slenderness of the deck beams and the whiteness of the facing panels are intended to emphasise the horizontal line.

The great width of the bridge and its low clearance have been played down. The alternation of tapering beams and dark voids breaks up the underside of the superstructure. The openings between the piers counteract the "tunnel" effect, and give a sense of space and light. The faceting of the piers reduces their apparent bulk and makes them look taller than they are.

The length of the bridge, between faces of abutments, is 1,100 ft.; the carriageway is 70 ft. wide, providing six traffic lanes. There are 8 ft. wide footpaths on each side, separated from the carriageway by a 2 ft. wide safety kerb and fence. The headroom specified for river traffic in the navigation channel was 26 ft. and for road traffic on the riverside roads was 15 ft. The

maximum road gradient is $3\frac{1}{2}$ per cent.

The bridge is designed to carry 80 per cent. of H.A. loading laid down in British Standard 153 and special vehicles of 75 tons. The bridge, in addition, carries five 30 in. diameter pipes for water and sewage, gas mains, electric and telephone cables. In all the total superimposed load exceeds full H.A. loading plus normal services.

The bridge has five spans—of 160 ft., 230 ft., 320 ft., 230 ft. and 160 ft.—and is designed to be fully continuous under live load. It is anchored at the north abutment and all expansion movement is provided for at the south abutment.

The bridge is founded upon long piles—180 in number—which support abutments and piers of reinforced concrete. The piers support reinforced concrete rocking columns which in turn carry the deck structure of prestressed concrete.

In order to achieve a pleasing appearance precast concrete facing panels are attached to the outer faces of the parapet beams. These panels are made from crushed white quartzite aggregate, white sand, and white cement; the aggregate is exposed on the surface, producing a light, rough, highly reflective surface which shows up to particular advantage in the strong sunlight and clear atmosphere normal in Perth.

The abutments also are constructed in white concrete, as are the cantilever structures forming the footpaths. The balustrades are of aluminium set in granite and the carriageway is flanked by polished granite pilasters at each end of the bridge, which carry commemorative plaques.

The carriageway is finished in asphalt laid by the Department of Main Roads.

Piling

The piles adopted are of a type invented by Mr. G. A. Maunsell and known as "Gambia piles" from the fact that he first used them in the Gambia. They consist of $31\frac{1}{4}$ in. outside diameter steel tubes with $\frac{3}{8}$ in. thick walls terminating in a conical steel toe. Reinforced concrete was placed in the toe of each pile for a depth of 15 ft. prior to driving, which was carried out by means of a 10-ton drop hammer operating inside the pile and delivering its blows on to a removable driving helmet lying on the concrete in the toe. Extensions to the steel tubes were welded on as required during driving.

The piles were driven through sands, silts, gravels and clays and were founded on very hard clay overlying a stratum of limestone.

After driving, the steel tubes were filled with reinforced concrete, the design being such that reliance is placed only upon the reinforced concrete core; thus corrosion of the outer steel tube is not a danger to the structure.

The piles have been designed to carry maximum dead loads of 200 tons each; these are increased to 250 tons by transient loads. The piles are thought to be capable of carrying more than 600 tons, and test loads of 400 tons were carried without measurable permanent deflection being recorded.

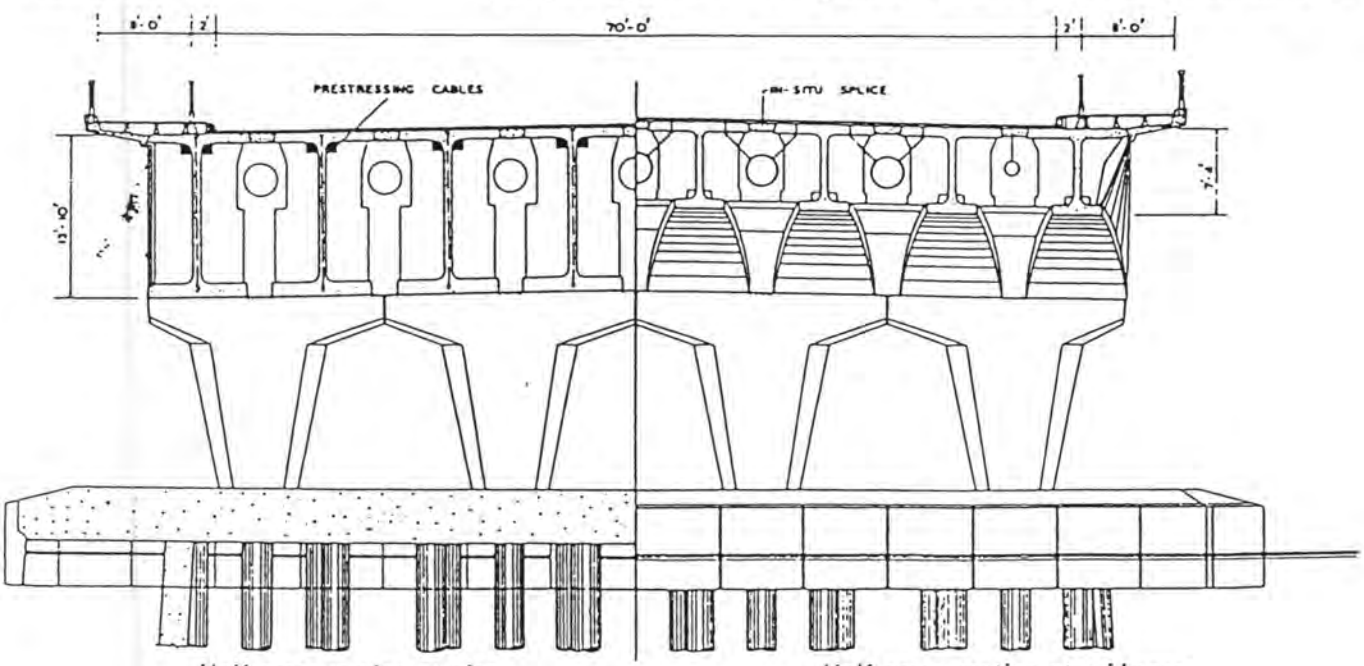
The piles for the north shore pier were of a modified design to allow for possible movements in the reclaimed ground through which they were driven. In this case, the upper 60 ft. of the pile consisted of a precast reinforced concrete column placed inside a 48 in. diameter steel shell after driving. The space between the two permits deflection with ground movement of the steel shell which is weak in bending, without transmission of the deflection to the precast concrete column supporting the bridge pier.

Abutments and Piers

The abutments take the conventional box form, except that a sloping suspended slab supported on internal walls is incorporated. The purpose of this slab is to ensure that the depth of filling supporting the carriageway tapers gradually from the full depth of the embankments on which the road runs as it approaches the bridge, to nothing. This gradual tapering, supported by the sloping slab, ensures that settlement in the abutment filling and the embankments, while it may result in changes of profile, will not lead to an abrupt step in the surface which would require urgent remedial measures. The void beneath the sloping slab is useful for the accommodation of the services.

The shore piers are of simple design, in reinforced concrete set in the ground, but in the river precast concrete skirt pieces were incorporated as permanent formwork to the structural hearting. The purpose of this was to enable the placing of structural concrete in the dry, without subsequently exposing the piles to view during low water periods.

The bridge columns are of reinforced concrete, each supporting two deck beams. Four columns supporting eight beams are provided at each pier. The columns are set on curved bearing plates and surmounted by similar plates, arranged so that both top and bottom curves at each pier form part of a cylindrical surface. The columns thus become in effect parts of large roller bearings of diameter equal to the column height, and permit the longi-



Half cross section at pier *Half cross section at mid-span*

tudinal expansion and contraction of the bridge to take place with the minimum of frictional resistance.

;Transverse expansion and contraction is provided for by means of nests of 7 in. diameter roller bearings set in boxes in the concrete of the piers. The boxes have been filled with dense tar, to prevent corrosion and the entry of rubbish and water. Transverse bearings are provided under three of every four columns. All bearing surfaces, which have been left dry, are of stainless steel.

Deck Structure

Close limits were set on the structural depths at certain points by the headroom requirements for the underpass roads and navigation and by the motorway levels and gradients. Within these limits, the length and proportions of spans were selected principally for appearance.

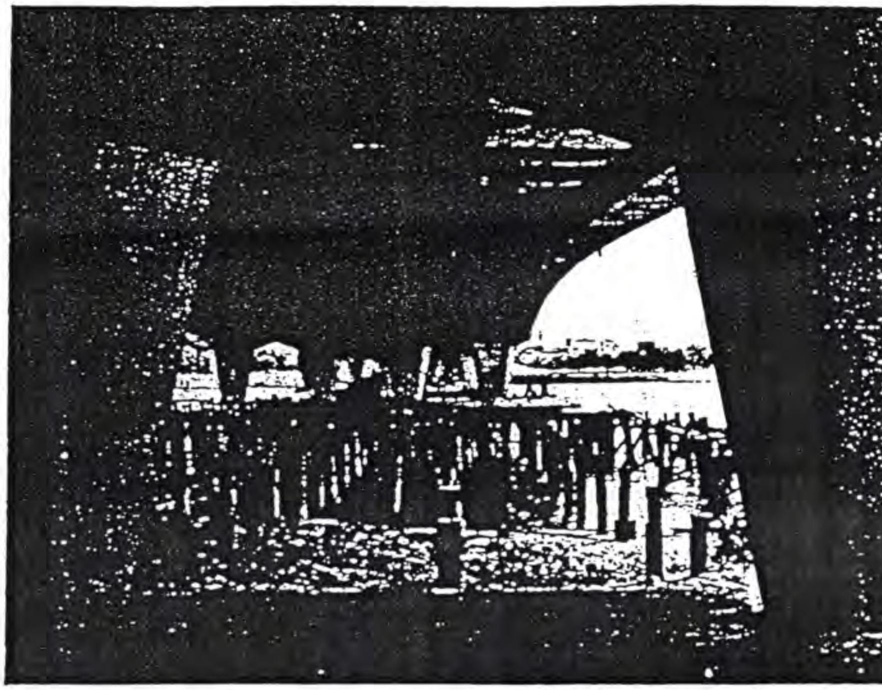
The beams of the deck structure are made up of precast units, which were jointed and stressed together in place.

The main beams were designed as double-cantilever beams with suspended spans for self-weight during erection but are continuous for all subsequent superimposed loads.

The unusual features of the deck structure are the external cables, vertical shear cables, the method of casting the precast concrete segments, and the method of obtaining continuity.

One of the requirements of an efficient concrete cross-section is that the webs and flanges should be as thin as practicable. This was found to be incompatible with the space requirements for the large prestressing forces required in this design. Consequently the longitudinal prestressing force was applied with external cables. This meant that the thickness of webs and flanges could be reduced to 8 in., as the only space required was for the vertical prestressing cables and mild steel reinforcement.

To achieve the maximum eccentricity, and therefore the maximum economy, the external cables needed to be as small as possible. The overall size of an external cable is governed by the space required between each tendon for the efficient placing of the protective concrete, and by the number of these tendons. For equal force, a small number of large strands will give a more concentrated cable than a larger number of individual wires. In a well designed strand, the outer wires grip the inner ones by the radial forces resulting from the spiral construction, so there is no need to bond these with cement grout. Experiments made by the designer in association with the Somerset Wire Co. Ltd., and Udalls Prestressed Concrete Ltd., led to the production of a nineteen-wire Seale's construction strand of 0.7 in. diameter



View showing construction of underside of bridge

to be used with a split wedge anchor grip. At the positions where the cables change direction the strands pass over lubricated machined steel saddles with such a low frictional resistance that the loss of prestress from this cause was only 4 per cent., or one-fifth of the value usually associated with long curved cables in ducts. The prestressing forces were accurately measured with load cells reading on mirror galvanometers. After completion of tensioning, the cables were surrounded with fine concrete to protect them from corrosion, and to bond them to the beam through mild steel shear bars passing through holes in the webs.

Vertical prestressing cables were used to reduce the principal tensile stresses due to shear in the thin webs, but these cables were not sufficient alone to resist the total shear tensions at ultimate load, so additional mild steel reinforcement was added. Because of the total lack of fundamental information on the behaviour of prestressed concrete beams in combined bending and shear, a one-third scale test-model was made to verify the assumptions that had been made. The test beam failed at precisely the predicted load, which had been calculated on the assumption that the shear forces would work as in a lattice beam, and that the main cable was fully bonded. The load factor was 1.95 on dead-load plus superimposed-load, which can also be expressed as 1.5 on dead-load and 4.4 on superimposed-load.

Because, in the designer's opinion, beams of this cross-section are unsuitable for in situ construction, the bridge was built with short precast segments with separate diaphragms. To further simplify the construction, the beams were detailed so that the bottom flange and lower section of the web were cast first. A few days later, the remainder of the section was cast in a second mould, which was bolted to the lower part of the web. The second mould could thus be of standard shape, as the variable depth of web and width of bottom flange were both accommodated in the first stage of casting. The units were transported from the precasting yard to the bridge on a light railway from which they were lifted by a Goliath travelling crane on to a piled staging of local Jarrah poles.

After a complete section of the staging for the double-cantilever beams had been loaded with units, these were adjusted for line and level with small screw jacks. The 3 in. wide joints between the sections were filled with fine concrete compacted with immersion vibrators.

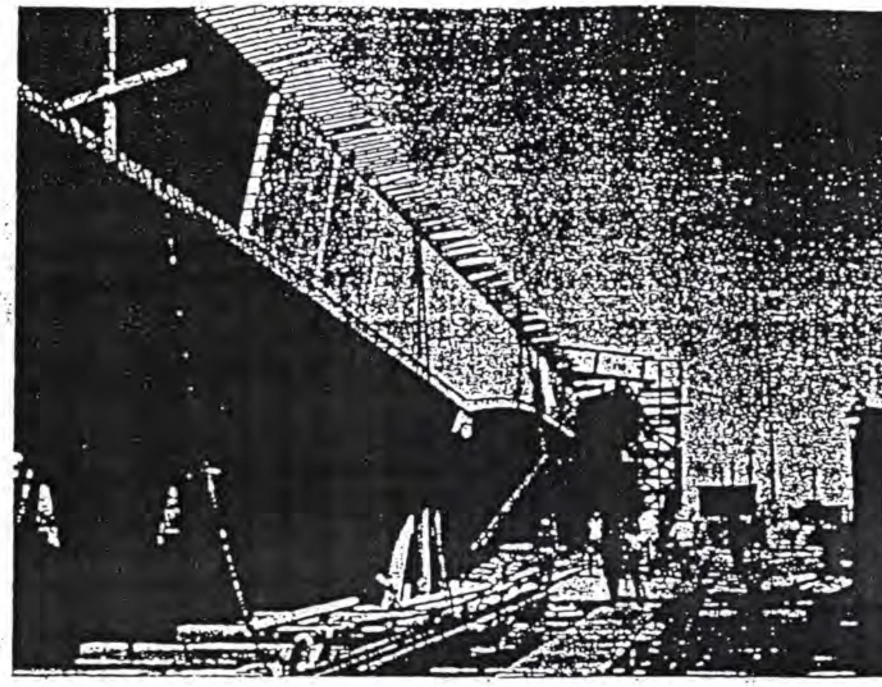
The primary strands of the main cables of the double cantilever beams were then threaded and stressed. The suspended spans were constructed above their final position to give access to the beam ends for cable tensioning. After completion they were jacked down until the halved ends of the anchor blocks rested on neoprene strips placed on the upper face of the halved blocks of the double cantilever beams. The temporary props which had been left beneath the centres of the beams were then removed, and the secondary main cables were tensioned. These cables have their anchorages in the top flange of the main beam.

After the transverse cables were tensioned and the in situ concrete deck splicing strips had been placed, the pre-

cast exposed quartzite aggregate facing panels were erected, and the cantilever footway slab was concreted.

The final operation to complete the superstructure was to make the beams continuous by fixing the temporary hinges. This was done by caulking the vertical joints between the anchor block faces with cement mortar and then clamping them together by tensioning short cables passing through ducts formed in the anchor blocks. These cables, which are standard G.U.12/0.276 in., were tensioned using the short-wire technique. They lap with the main strand cables and thus give complete continuity.

The type of expansion joint adopted is that manufactured by the Demag Company of West Germany. It consists of heavy articulated cast steel plates running on steel ramps, and is designed to provide a continuous running surface while allowing for a variation of 7 in. in the length of the bridge deck.



View showing precast concrete facing panels in position

Stresses

Concrete

Bending compression—initial, 2,500 lb. per sq. in.; service, 2,300 lb. per sq. in.

Bending tension—nil.

Principal tensile stress due to shear—150 lb. per sq. in.

Specified minimum 28-day strength of 6 in. test cubes—6,500 lb. per sq. in.

(Actual strength obtained was about 8,500 lb. per sq. in., with a standard deviation of approximately 500 lb. per sq. in.)

Steel

Initial stress in strands (equivalent to 26.5 tons/strand)—83 tons per sq. in.

Final stress in strands (equivalent to 20 tons/strand)—63 tons per sq. in.

Finishing

The careful design and skilled manufacture of the balustrades and lamp standards has contributed considerably to the fine appearance of the bridge as a whole. These items were made of anodised aluminium alloy. A pleasing effect has been obtained by incorporating a dark grey with the normal light grey of the main balustrades. The sections for the main balustrades and the safety fence were extruded in Australia, but the poles for the lighting standards are of Swiss manufacture.

Quantities

The bridge construction required the following quantities of material:

Concrete	10,850 cu.yd.
Reinforcement ..	1,310 tons
Steel tube for piles ..	1,215 tons
Prestressing wire and strand	325 tons

The thickness of the theoretical slab of equivalent concrete quantity to the deck structure is 23 in. The weight of high tensile steel in the deck structure per square foot is 7.5 lb. and the corresponding figure for mild steel 19.5 lb.

The total cost of the bridge, expressed as a cost per square foot based on the gross area of the deck and abutments, is approximately £11 15s.

Bath Road Improvements

The Minister of Transport has announced that three pedestrian subways are to be built under the London-Bristol trunk Road (A.4) at Cranford, near London Airport, at a cost of about £115,000. They will be sited at intervals of between 300 and 400 yards along a stretch of A.4 which includes the busy shopping area of Cranford Village.

The contractors, Leonard Fairclough Ltd., of Adlington, Lancs., who have just been awarded a contract worth £92,000, will start work on the actual subways in mid-December, although a lot of preparatory work has already been done. They expect to finish the contract by the autumn of next year.

The subways, to be built in reinforced concrete with ramps and stairways, form part of a £500,000 road improvement scheme.

Stage 1 of the scheme is the construction of two 24-ft. carriageways on the 1¼ mile length of A.4 from west of Sipson Road to Cranford Hall Garage. Begun in June, 1958, this work is now nearing completion.

Stage 2—the provision of dual carriageways on the mile-long stretch between Cranford Hall Garage and Henly's Corner (where A.4 is joined by A.30)—is due to start next Spring. As pedestrians already have difficulty in crossing the road, the subways are being provided in advance of the main roadworks.

The roadworks have been designed for the Ministry of Transport by the county engineer of Middlesex County Council, Mr. H. S. Andrew, M.I.C.E., M.I.Mun.E. and the subways by the consulting engineer, Mr. Harry Brompton, B.Sc., M.I.C.E., M.I.W.E., M.I.Struct.E.

The Medway Motor Road

Planning of the new Medway Motor Road reached a new stage when Mr. Ernest Marples, Minister of Transport, published draft Orders under section 3 of the Special Roads Act on November 16 last. The Orders provide for alterations to public roads and footpaths. These alterations are necessary because access to the road will be limited to a few junctions with existing major roads. The alterations include re-alignment and regrading of 105 side roads, the construction of 82 new lengths of public highway, including footpaths and bridle roads, and the provision of new means of access to private properties affected by the construction of the new road.

Details are given in the draft Orders, schedules and plans which can be seen at the offices of local authorities concerned. During the next three months any person may make representations to the Minister or lodge objections to the making of the Orders.

One of the draft Orders deals with the sections of road on either side of the proposed Medway Bridge, on which work is due to start early next year. The other Order deals with the main line of the Motor Road, the construction of which is expected to begin early in 1961.

It is hoped that the whole Motor Road will be completed by the end of 1962.

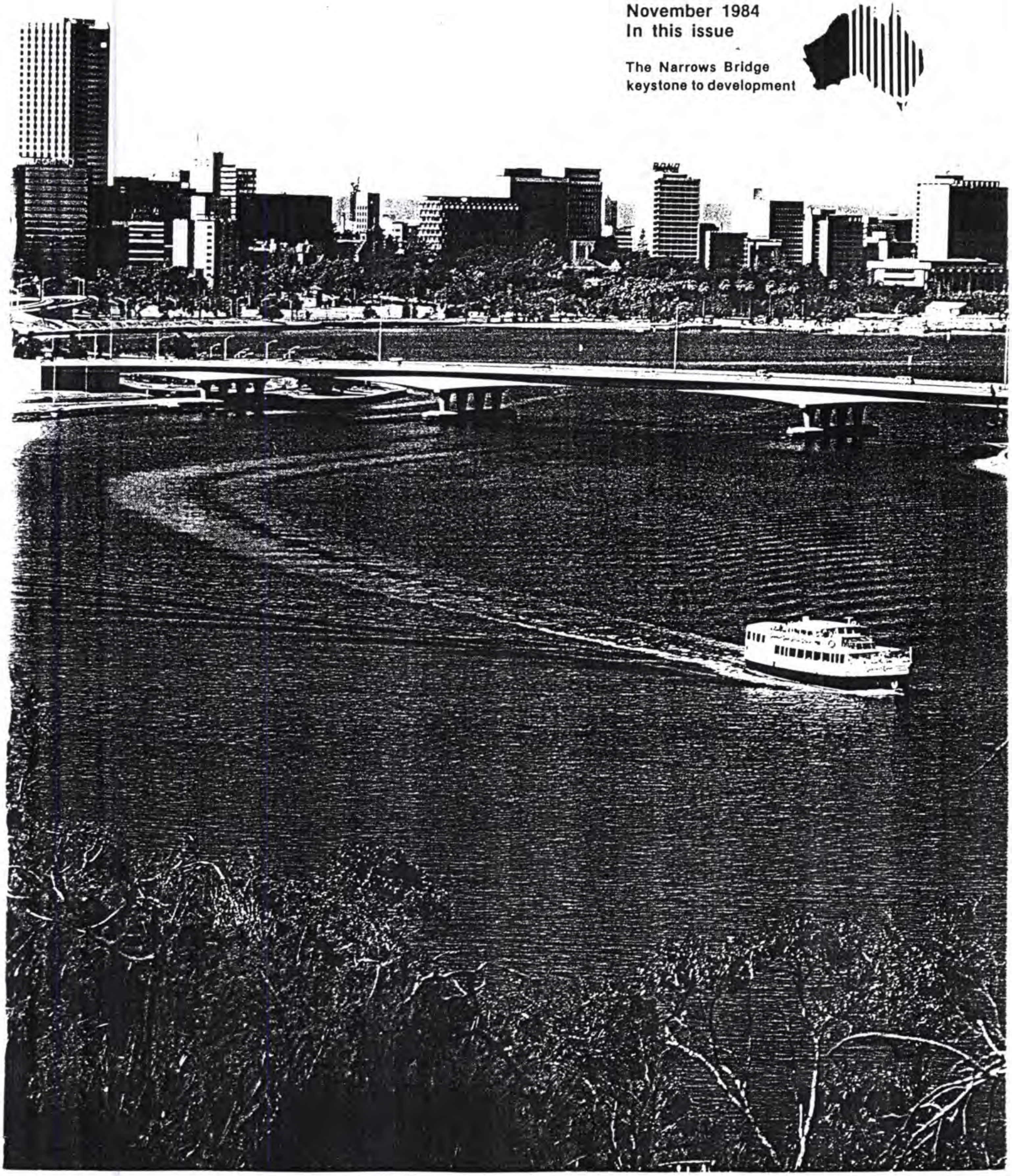
ATTACHMENT 9

Narrows Bridge, Western Roads November 1984

western roads

November 1984
In this issue

The Narrows Bridge
keystone to development



western
roads

NOVEMBER 1984
Vol. 9 No. 4

This is a special issue of Western Roads, the quarterly journal of the Main Roads Department of Western Australia. It tells the story of the far-reaching effects the construction of the Narrows Bridge has had on the development of the Perth Region.

Front Cover:

The Narrows Bridge, seen from Kings Park.

Back Cover:

The bridge seen from the 31st floor of Allendale Square.

WESTERN ROADS is published for the Commissioner of Main Roads, Perth, Western Australia.

Commissioner of Main Roads, Waterloo Crescent, East Perth, Western Australia.

Foreword

Whatever vantage point one chooses—a Kings Park lookout, a car cruising towards Perth's burgeoning south, the deck of a Rottnest ferry, or an office tower on the city skyline—the Narrows Bridge inspires a sense of pride, and perhaps an awesome awareness of how it has influenced the shape of Perth over a quarter-century.

Today, the Bridge and the Mitchell and Kwinana Freeways have accelerated Perth's axis of development north and south, away from the east-west emphasis of years gone by. The pattern is firmly cast for Perth's future growth and prosperity.

Successive State Governments under six Premiers can take credit for the positive vision behind this achievement. In 1954, Hon John Tonkin, as Minister for Works in the Government of Hon Bert Hawke, put the Narrows Bridge proposal to Cabinet and gained its support. The Bridge was opened during the time of the late Sir David Brand's Government, and the development of the freeway system and other major roads has continued through the Tonkin, Court and O'Connor Governments, and now the Burke Government. This commitment to progress regardless of political stance has made Perth the envy of cities the world over.

Public transport, pedestrians and cyclists have by no means been forgotten in Perth's major road development. We can point to initiatives which cater specifically for buses and accord them special priority, and also to our expanding cycle network, our pedestrian bridges and our sensitive landscaping.

The immediate future will bring further extensions of the Mitchell Freeway, with completion to Hepburn Avenue by 1986. (Proposals for extension to Joondalup Drive are being examined). The Narrows Bridge itself is nearing the limits of its traffic flow capacity and the feasibility of increasing this capacity is at present being examined.

I compliment the Commissioner of Main Roads and his staff on their fine contribution to Western Australia's development. May the next twenty-five years be as fruitful as the last.

J F Grill
Minister for Transport

The Narrows Bridge is the central link in Perth's north-south freeway spine and the hub of modern-day metropolitan planning. The opening of the Bridge on November 13, 1959 enabled the stage-by-stage development of the freeway system to improve access to the north and open up areas to the south. It heralded a new era of growth and development in the Perth region.

This commemorative issue of "Western Roads" traces the history of the Narrows Bridge and gives some insight into the planning which has shaped today's Perth. As the story unfolds, we can see the challenges that have been met and perhaps perceive some of those that are yet to come.

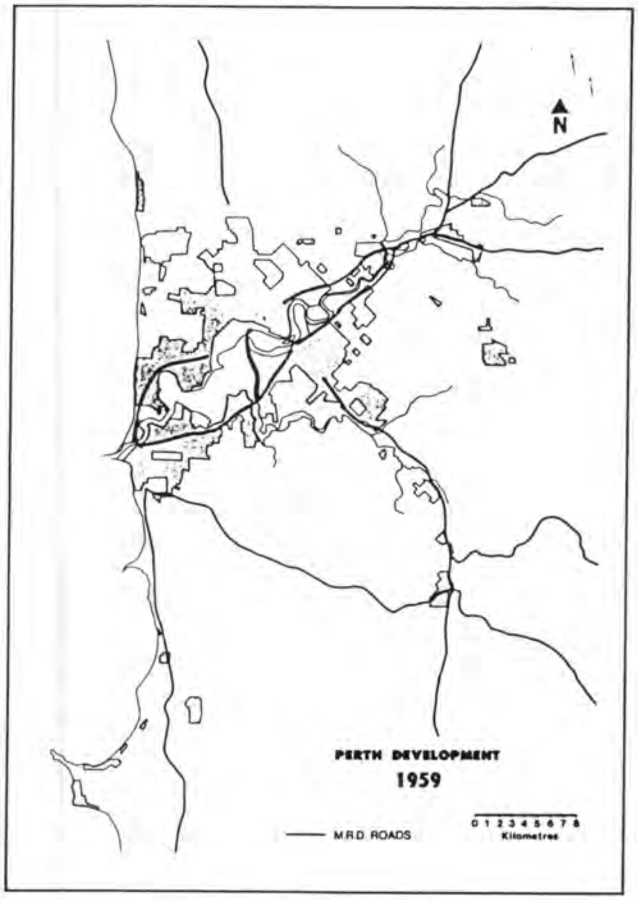
The Narrows Bridge marked a turning point in bridge design in Australia, being one of the country's first major prestressed concrete structures. Unique problems at the site prompted the engagement of overseas design skills, and the construction was carried out by an overseas firm in partnership with a local firm. The resulting transfer of knowledge to Australian engineers remains evident in bridge practices to this day.

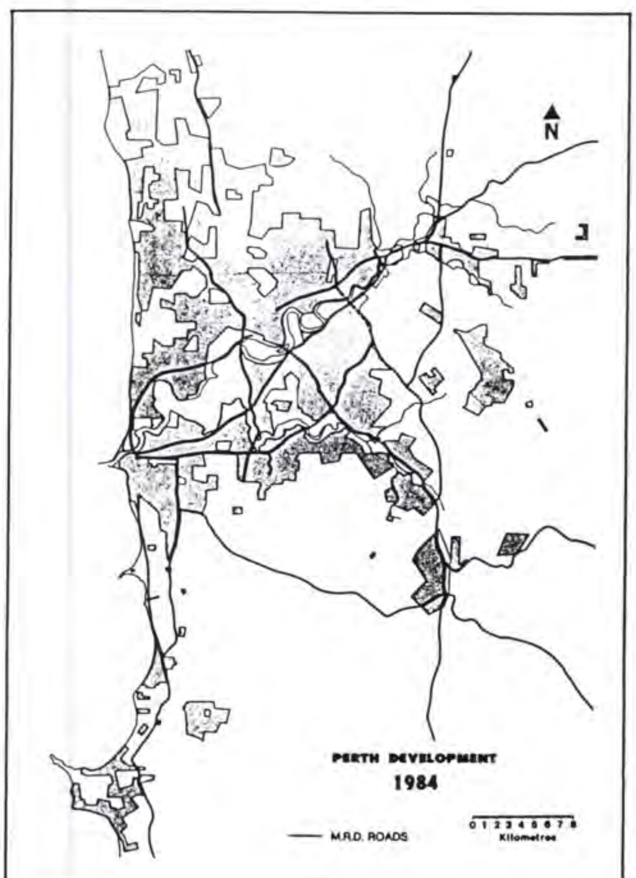
The visual importance of the site stimulated a heightened awareness of aesthetics among Perth's engineers, planners and architects. The Bridge, coupled with the parkland setting of the Narrows Interchange, have given a lead to structural proportioning and landscape technique which is now reflected in works throughout the State.

Co-operation is the key to development of a major road system. My Department has close associations with the Metropolitan Region Planning Authority as well as many other State and Local Authorities, and is assisted by many consultants and contractors. The dedication, enthusiasm and professional skills of the staff of the Main Roads Department have been vital ingredients to this success.

I commend to you this special edition of "Western Road" on this twenty-fifth anniversary of the Narrows Bridge.

D H Aitken
Commissioner of
Main Roads





PREFACE NARROWS BRIDGE

Keystone to Development

The Narrows Bridge was opened 25 years ago on November 13 1959 bringing to reality a dream that people had held for such a river crossing since much earlier in the history of the State.

In fact, rather than being the culmination of a dream it represented the start of a new era of major growth and change. The bridge is a key link in the growing Metropolitan Regional Road System.

The decision to build the Narrows Bridge was taken when the Stephenson, Hepburn Report was being prepared in which the basic shape of the future city was outlined including the future major road system. This concept was given strength when the Metropolitan Region Scheme came into operation on October 30 1963. Since then, projects undertaken by the Main Roads Department have aimed at developing the road system to provide a network of regional roads which will provide safe and rapid access throughout the Metropolitan area taking much of the heavier traffic flows and many of the heavier transport vehicles out of the Metropolitan street system.

It is worth reviewing the work that was involved in constructing the Narrows Bridge and its approaches on the 25th Anniversary of its opening, together with the progress made with the construction of other parts of the Regional Road System during those 25 years.

Initially in terms of length of road completed progress was very slow because of the extent of the difficulties involved in the task. For more than the first half of this period all available money and resources were absorbed by the work necessary to provide for the Narrows Interchange approaches to the new bridge and the construction of the freeway through West Perth to Hamilton Square just north of the railway line. Only in the last decade has substantial progress been made in extending the length of the road system along the routes reserved in the Metropolitan Region Scheme.

The following pages trace the progress made by the Main Roads Department in the development of the region's major road system.

INTRODUCTION

"Because of its youth, it is possible for the (Perth) Metropolitan Region to have a road system superior to those of nearly all other great cities, but it will require fairly immediate action if future possibilities are to be reserved."

G. Stephenson and J.A. Hepburn 1955

In their 1955 report on a plan for the Metropolitan Region, Perth and Fremantle, Stephenson and Hepburn* threw down the challenge that was to be picked up and acted upon by the Main Roads Department of Western Australia.

Perth Water in earlier days seen from where William Street currently joins the freeway.

In the mid 1950's the State was emerging from its "Cinderella" status and was approaching a period of rapid economic growth. Those with vision could foresee the future demands that would be placed on the State's capital city, particularly the pressures that would arise from a rapid increase in population.

The 1955 Report referred to above was to lay the foundation for the modern city we see today. The key element in the plan; and in any city plan for that matter, is the regional road network. Unless the proposed road system can cater for the traffic that will be generated in accordance with the needs of that plan, the region simply cannot develop as planned.

When this Report was written the country roads leading into the city were being widened and the demand for major new roads was only just being appreciated. The city had a population of under 400,000 and was predicted to grow to 1,000,000 by 1985 (it is estimated that Perth will reach a population of one million persons this month, November 1984). There were only 80,000 vehicles registered in the Perth Region; this has now increased to almost 580,000.

Despite the relative youth of the city the needs of the future were appreciated by the planners and action was taken to enable these needs to be satisfied. While the Plan for the Region was being evolved the Main Roads Department was surveying future road alignments and acquiring land for eventual construction. This early purchase of land has enabled the Department to build a modern road system with comparatively little disruption to local residents and the general public considering the road length involved.

Once the concept for city growth had been accepted, a decision was made to build the Narrows Bridge, the central and most vital link in the future regional road system. This led to the adoption of a simple strategy by the Main Roads Department whereby:

1. Work would be undertaken to the north and south of the Narrows Bridge, working outwards from the centre, to full freeway standards.

2. Available funds would be allocated to ensure that the balance of the major road network would be developed in stages as the need arose.

Prof. Gordon Stephenson.

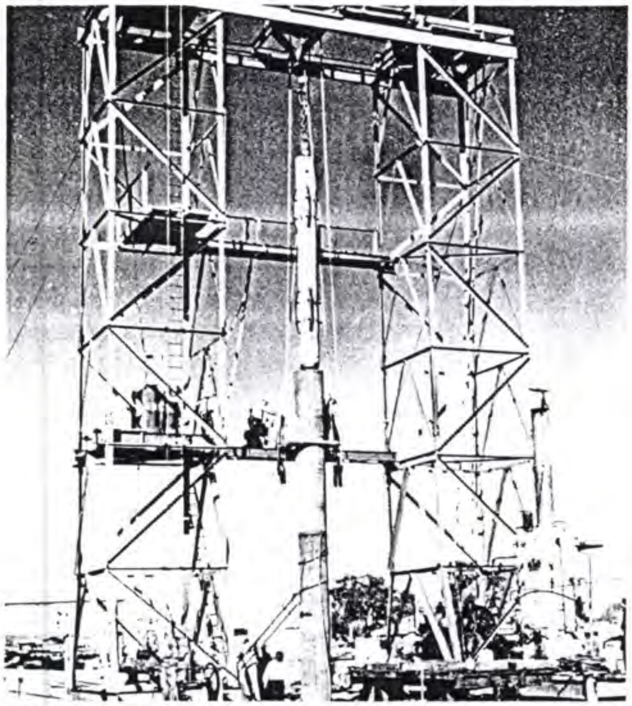
The corridor of public land was set aside for the freeway, without hindrance to adjacent private development.

**Gordon Stephenson and J.A. Hepburn, Plan for the Metropolitan Region, Perth and Fremantle, Government Printer, Perth, 1955. Mr Alastair Hepburn was W.A's Town Planning Commissioner from 1953 to 1959. The late Mr John Lloyd carried on Mr Hepburn's work as Town Planning Commissioner between 1959 and 1972, the year before his death.*

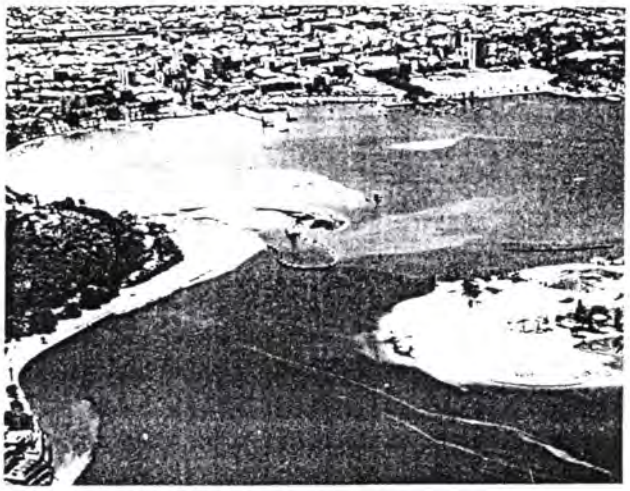
NARROWS BRIDGE AND APPROACHES

The Government, recognising the need to bridge the Narrows with a structure that would alter the face of Perth made arrangements for the Bridge Engineer of the Main Roads Department, Mr E.W.C. Godfrey to travel overseas in 1955. He was to inspect world class bridges in similar locations and recommend consultants to design, specify and supervise construction.

The visit resulted in the appointment of Maunsell and Partners and Cabinet approval to scheme plans in 1956.



Driving a hollow steel pile with an internal hammer suspended from a frame.



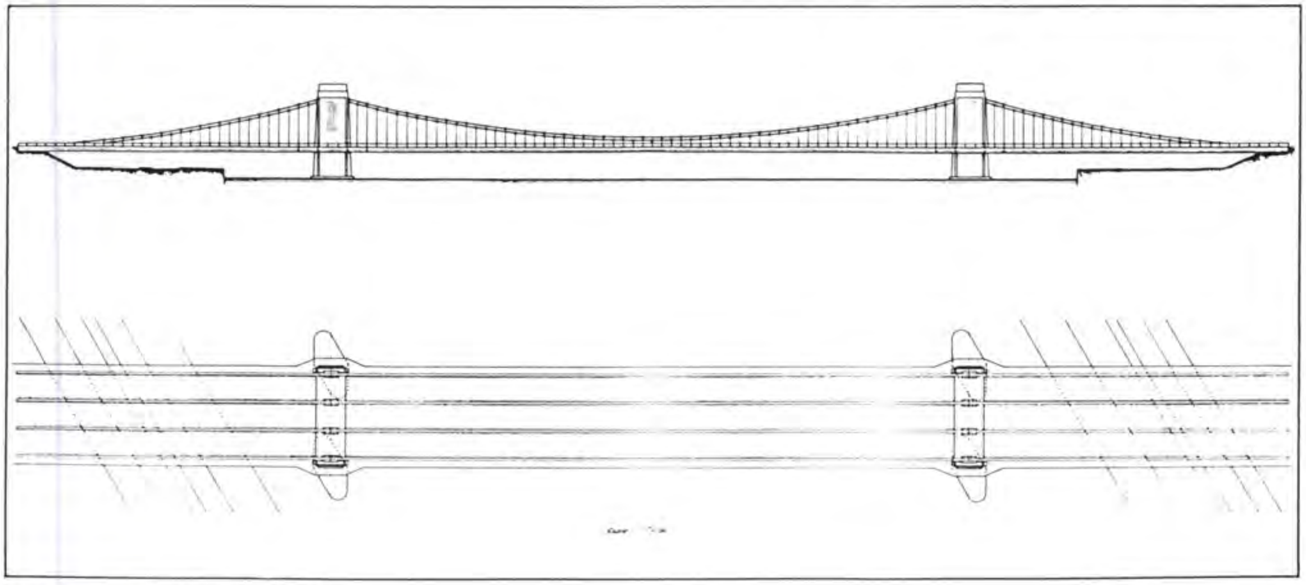
Reclamation in Perth Water marks a start on the Narrows Bridge.

Following detailed design, a contract was awarded in March 1957 to the construction company, Christiani and Nielsen, in association with the West Australian contractors, J.O. Clough and Son, for $2,650,005, a huge sum in those days.

Preceding construction of the bridge 29 hectares of Mounts Bay was reclaimed commencing in 1954 to provide for a future road interchange. This required the main river channel over which the bridge was to be built to be moved a considerable distance southward.

The design of the bridge provided six road lanes with footpaths each side. Construction was to be in concrete of five spans varying in length between 48 and 96 metres and having an overall length of approximately 336 metres and actually commenced with the driving of the first pile on August 14 1957.

Needless to say, and as is the case in all great public works, none of these early steps were free from criticism and controversy. 'Too ambitious', 'vandalism', 'Mounts Bay

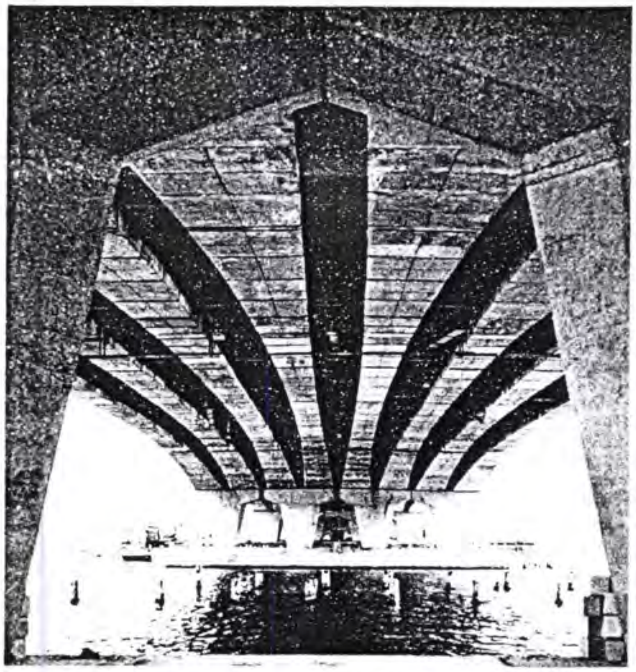


An early design for the proposed bridge.

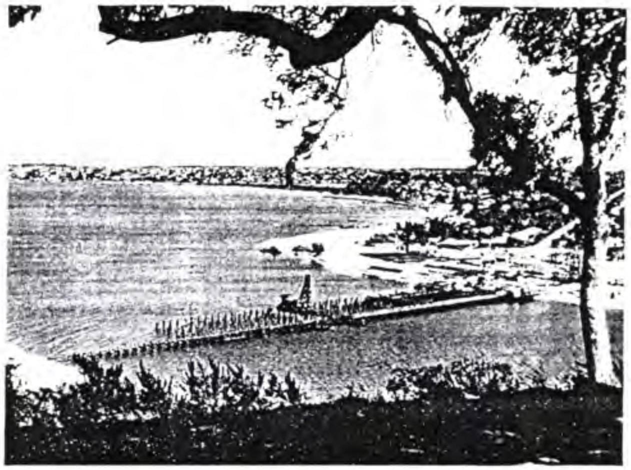
Road trees will be cut down', 'the South Perth Old Mill will be destroyed', 'the river will be destroyed', 'tunnel under Kings Park' were some of the cries. It seemed that everyone wanted a bridge, but not this one or if this one, not in this location.

Construction of the Narrows Bridge

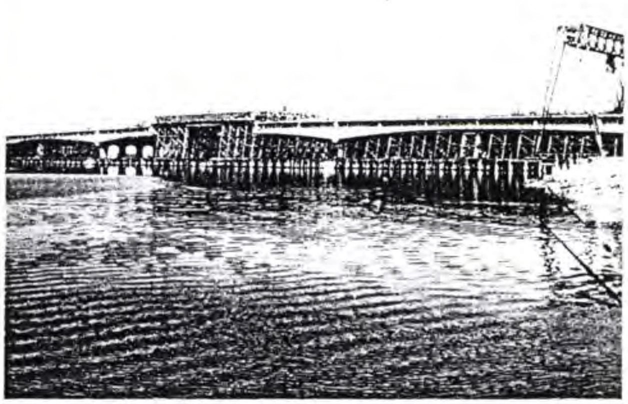
Now committed, foundation piling continued in earnest in difficult engineering conditions. A picture through the site would show shale (a soft rock) some 40 to 50 metres down across the whole site. Overlying the shale are beds of sand with clay intrusions with thicknesses between 10 and 20 metres. On top of this again until only about 4 metres of water was left are very soft organic silts.



The reinforced concrete pier system of the Narrows Bridge. In the foreground temporary erection piling awaits removal.

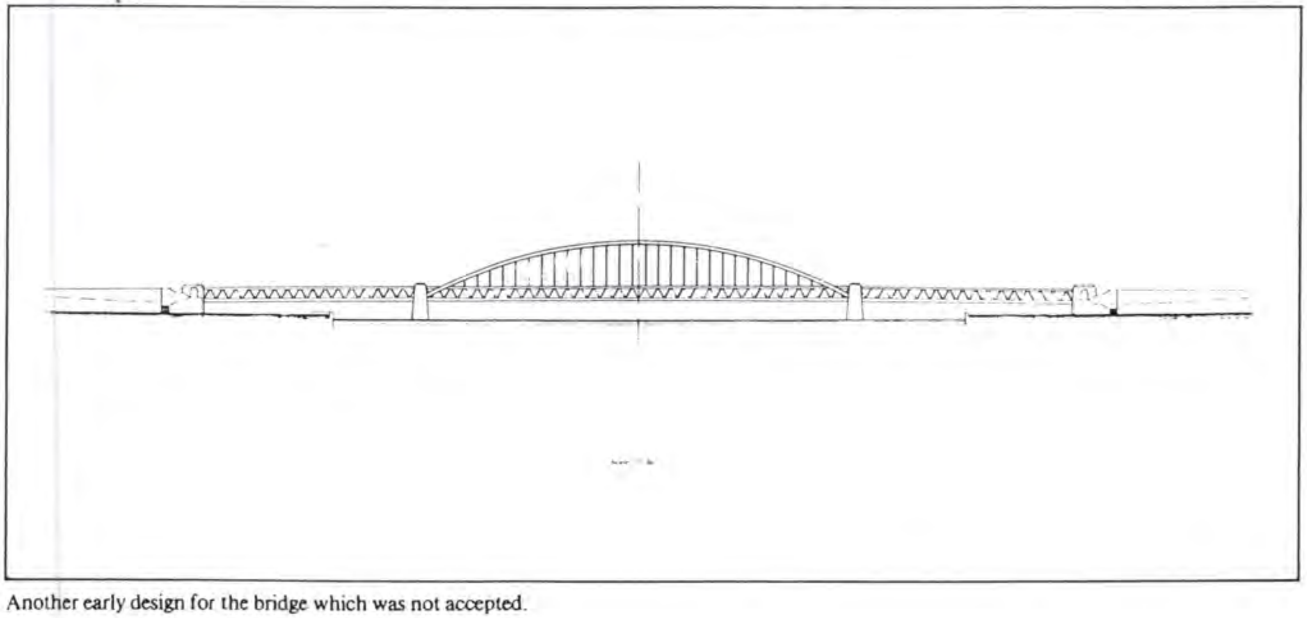


Temporary erection piling being driven.



The central navigation span for river ferries through the timber staging.

Large diameter hollow closed ended steel piles were chosen to support the piers of the bridge. After full depth driving, the tubes were reinforced, concreted and test loaded to 400 tonnes, twice their working capacity. The pile groups were



Another early design for the bridge which was not accepted.

then capped with reinforced concrete and skirted so that the unattractive jumble of piles would not show at low tide levels.

The sixteen columns of the four internal piers were then built in reinforced concrete to act as a support between the piling and the deck and provide a clearance of 8 metres and 4.6 metres over the water and roads.

To complete the substructure, pile supported abutments were built at each end to contain the approach ramps, accept the loads from the ends of the bridge and terminate the multitude of public utilities.

While this work was proceeding, attention was given to both the construction of the bridge deck and the method of erecting it. Designed to be formed from precast components, concrete plant, storage areas, yard gantries were all assembled on the Mill Point foreshore. A virtual forest of timber was obtained to form temporary erection staging. The timbers were driven into the ground, coupled and braced for the full width and length of the bridge to carry the weight of the precast segments. A navigation opening was provided for river ferries. Span by span, the eight rows of segments were separately placed on this staging and concrete jointed both transversely and longitudinally after assembly.

Footpaths, light standards and railing were part of the completion works.

Designed as a twin double cantilever with drop in centre and end spans, assembly was temporarily completed at different levels to allow initial prestressing to be carried out.

Following this, staging was partially removed and the drop in spans were lowered to form the final vertical profile and final prestressing was carried out.

Dressing commenced when the bridge skeleton was complete. Concrete surfaces were bush-hammered, lighting and railing added, sides clad in exposed aggregate panels, temporary staging and construction debris cleared away and the asphalt surfacing applied.

Approaches to the Narrows Bridge

Concurrently with the bridge building activities two separate major tasks were undertaken, the northern approaches to the bridge and the Kwinana Freeway connecting the Narrows to Canning Highway.

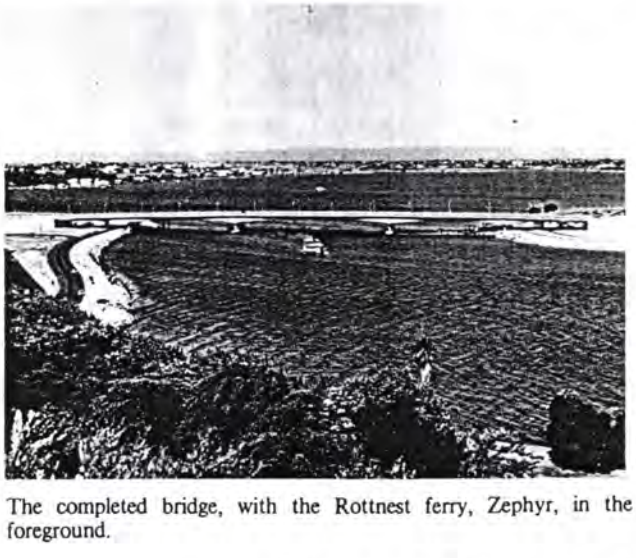
For the anticipated volume and speed of traffic approaching the bridge from the north, a total of about 29 hectares were reclaimed from the 356 hectare area of Perth water. The ground conditions were a dredge master's nightmare. The shallow section of Mounts Bay was reclaimed to cover a depth of up to 30 metres of mud. Pumped 'fill' was placed behind a marginal line of sand and shell placed in turn by grab and suction dredges from materials stockpiled earlier. 1,350,000 cubic metres of mud was placed this way, much of it requiring double handling. The reclaimed area was then covered with a skin of sand in varying thickness from 0.3—1.5 metres and on this skin grass was planted and roads built. At the northern bridge abutment the mud was displaced to its full depth to provide a firm foundation.

The siting of the bridge also made possible an adequate road connection to Canning Highway with control of access providing for fast free moving traffic. This road, the Kwinana Freeway, was located largely on land previously reclaimed from the river by suction dredging. Three off-ramps and two on-ramps (one of them at Cale Street as a temporary measure) were provided.

Five prestressed concrete footbridges were strategically placed over the roadway so that safe access to the popular beach frontage along Melville water was preserved.

As these works all drew to their conclusion, controversy again errupted over naming the work. First selected was the Golden West Freeway and the Golden West Bridge. Unanimous and vigorous public criticism calling the names 'a vulgar plagiarism', 'unoriginal', 'awful', 'corny', 'detestable' and the like carried the day and finally the Narrows and Kwinana were accepted by all.

And so, in a little over two years since work commenced all three projects came together on November 13 1959, when the Governor, Sir Charles Gairdner, declared the work open to the public. The Narrows Bridge was connected by temporary roads northwards to Mounts Bay Road and the city centre street system, the Kwinana Freeway extended southwards to Canning Bridge and access to Mill Point Road in South Perth was possible by temporary ramps.



The completed bridge, with the Rottnest ferry, Zephyr, in the foreground.

NARROWS INTERCHANGE

Once the construction of the Narrows Bridge was complete, work was concentrated on the area to the north. An immense task lay ahead to complete the Narrows Interchange and develop the road system that was necessary to cater for the northerly extension of the freeway and the needs of traffic destined for the city centre. In the latter stages of this work a start was made on the short length of freeway between Mount Street and Murray Street which would take the freeway past the centre of Perth.

Construction of the Narrows Interchange can be separated into two distinct, but related areas—land works and bridge works. Both works were conditioned by the need to work in an environment of extremely soft ancient river muds. These works were extremely complex because of the site conditions and were to take almost a decade to complete.

Land works—Reclamation

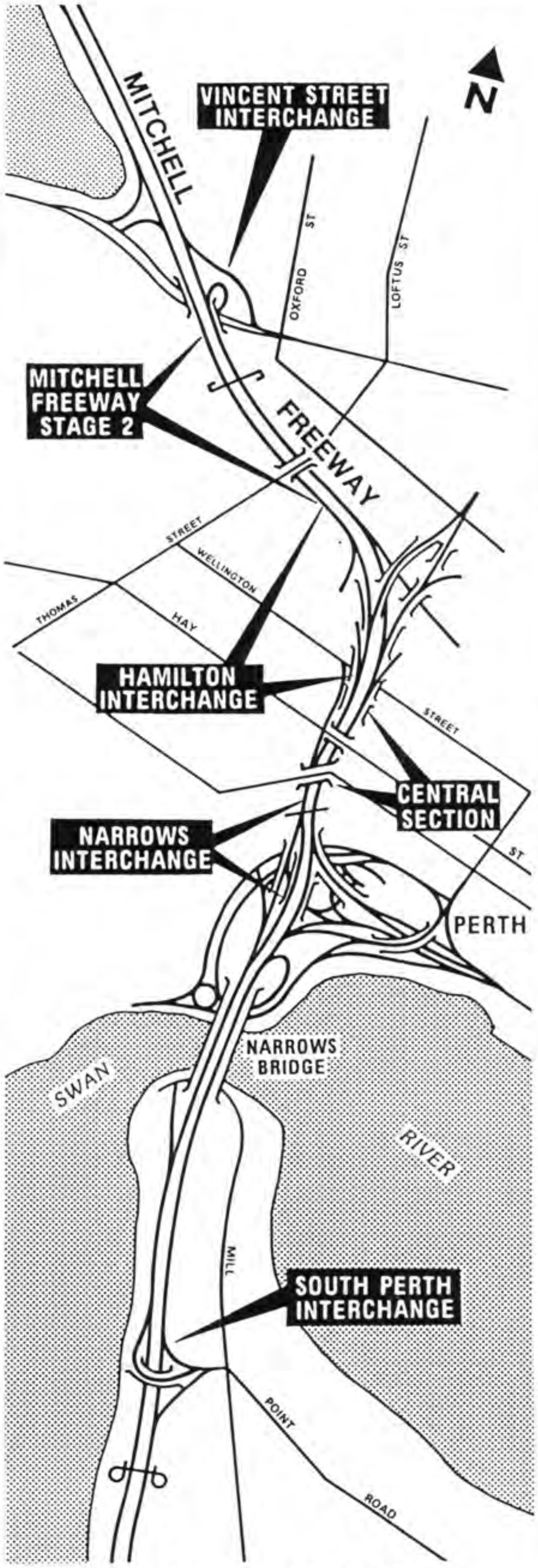
The whole interchange area is underlaid by the ancient river bed which was a rather sharply defined ravine, filled by deep deposits of alluvial mud with an average general maximum depth of 21 metres. Some 29 hectares of the site had been reclaimed from the river in the approach roads to the Narrows Bridge and a further eight hectares were to be reclaimed for the interchange area. Essential reclamation was carried out by hydraulically placing mud behind a sand perimeter wall. After drying out, mud was covered with a one metre thick sand blanket on which roads could be built to clear the area of subsequent work.

Based on an aesthetic decision to build a parkland interchange as an alternative to a multitude of bridge works, the construction task was to consolidate these soft muds to a state of sufficient strength to accept large embankments and other landscaping works. The mud existing at the site was only capable of supporting banks to a height of about two metres without failure and was extremely compressible.

Sand Drains

The next construction stage after reclamation was twofold, being to increase the strength of the mud and to cause it to consolidate or settle prior to the building of any permanent roadworks. The technique used was unique to Australia and involved the placing of vertical sand drains in a grid pattern throughout the whole area. These drains are driven at centres varying between 1.5 metres and 3 metres in a regular pattern, the pattern depending on the depth of mud, the height of embankments and the relative importance of the location. Being filled with relatively coarse sand these drains permit the relatively rapid loss of water from the mud when the load is applied, but even so, some 3 years were needed for adequate water loss to occur.

43,708 individual drains were installed with a cumulative length of approximately 800 kilometres at a cost of $1.35



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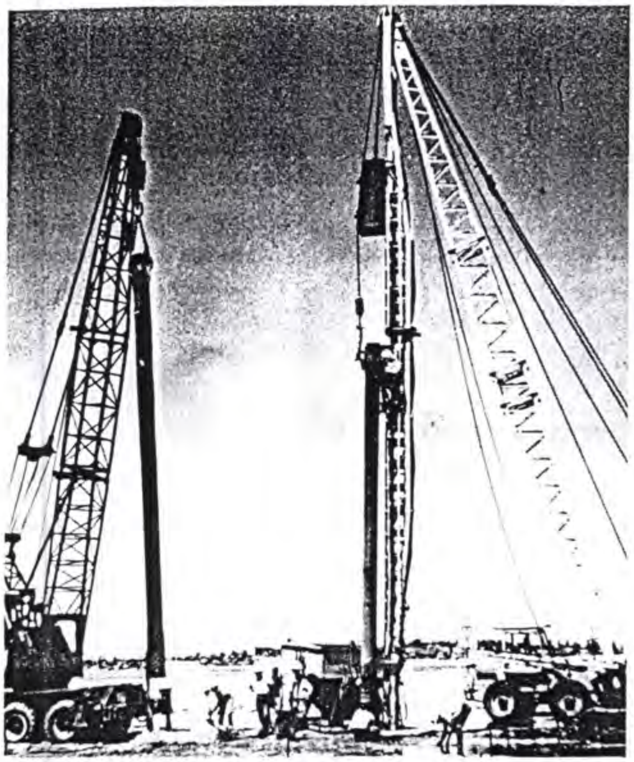
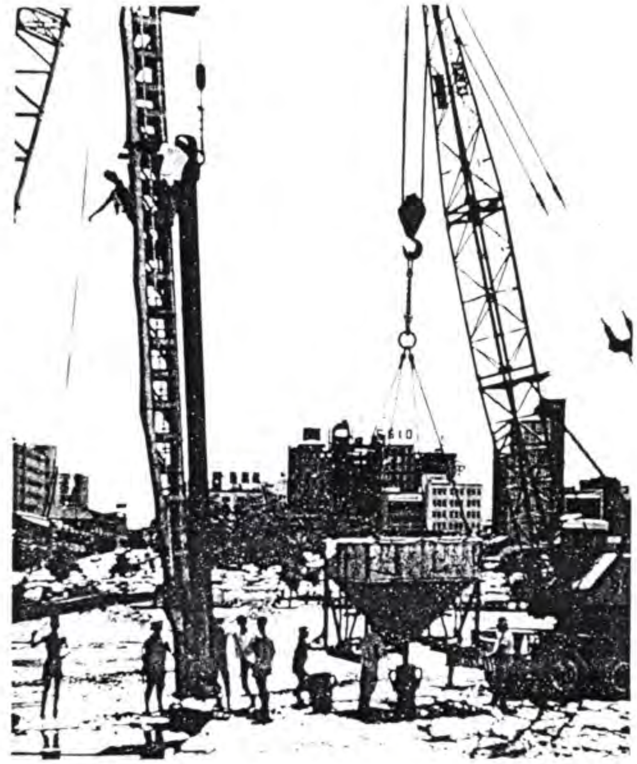


The crane on the right drives a hollow steel mandrel while the crane on the left extracts a mandrel ready for sand filling.

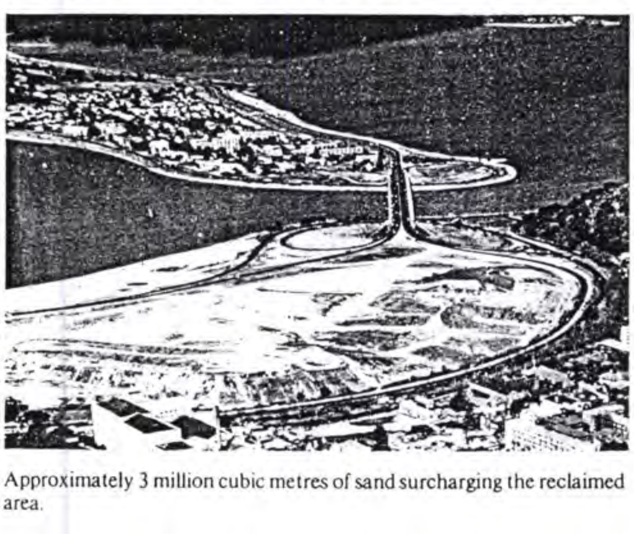


Loading the vertical drain with sand.

per metre. The volume of sand placed in the drains was 146,000 cubic metres which, together with the 500,000 cubic metres used for reclamation, brought the site to a condition where the third earthworks stage could commence.

Embankment

To cause the pressure differential required to force water from the mud, thus obtaining strength gain and consolidation, an embankment was built above the drains using a total of 3.1 million cubic metres of sand. The construction of this bank with its sensitive boundary areas of rivers and car parks was only made possible in the time available by the use of computer and analysis of failure patterns—the first such use in Australia.



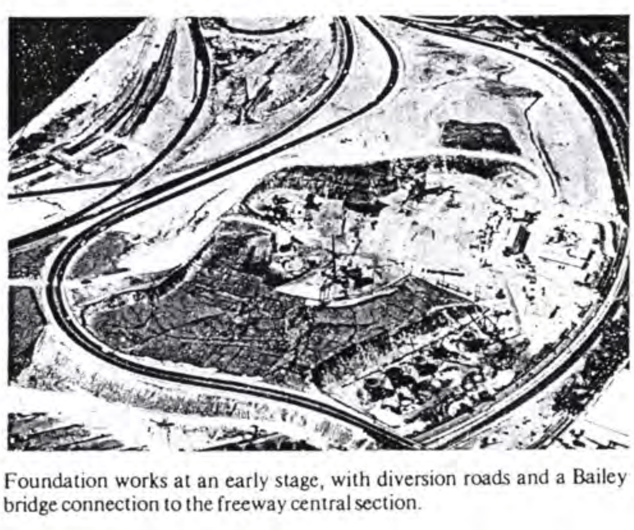
Approximately 3 million cubic metres of sand surcharging the reclaimed area.

At the time of commencing construction of the bridge works, the results achieved were a 14-fold gain in strength and a consolidation brought about by the volume of water squeezed from the mud of up to eight metres.

Bridge Construction

During bridge design it became apparent that the foundation solutions would be of an unusual, if not a unique, nature due to the consolidating mud which would be encountered. For this reason, it was decided to split the work into two areas, one being foundations and the other superstructures, in an endeavour to ensure that a specialist could be obtained in each field of work.

The strata through which the foundations were to be



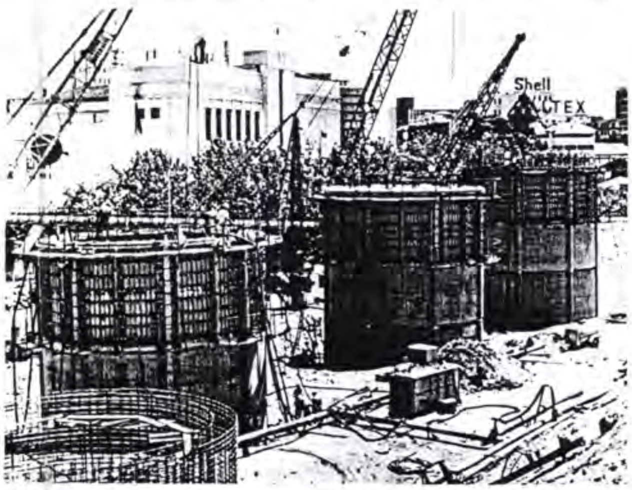
Foundation works at an early stage, with diversion roads and a Bailey bridge connection to the freeway central section.

built were still settling vertically and had an associated horizontal movement so that any standard solution, such as piling, would have to be able to sustain both vertical friction loads and horizontal deflections to a degree beyond normal capabilities.

The solution adopted by the Department for each support was of two parts:

1. An outer caisson (with diameters up to 10 metres) articulated at 3.6 metre intervals throughout the mud layers. The articulation into segments allows the horizontal movement and friction loads to be accepted on this element without transferring it to the bridge foundation structure itself.

2. Within this caisson, and isolated from it by an approximate one metre annulus, a slip form pier was built founded on the bedrock and taking solely bridge loading.



Caisson construction for the bridge over Mounts Bay Road.

Prestress

Prior to completing the design of either the foundations or superstructures, one of the largest single prestressed contracts ever awarded in Australia was accepted and in turn nominated to the site contractors. Doing this permitted the completion of final designs and the stockpiling of many tonnes of materials imported from England.

Subways

Three pedestrian subways were completed concurrently with bridge works to link paths through the landscaping and safely separate traffic and people. As for the bridge foundations, the subways had to be articulated into segments which would accept the ground movements. The subways provide a through movement and connections with footbridges linking both the City No 2 Car Park and Kings Park.

Temporary Roads

During construction of all phases of works, temporary roads were repeatedly constructed to maintain the 60,000 vehicles per day passing through the interchange site and using the Narrows Bridge, and at no time was that bridge removed from public use.

Lakes and Landscaping

Three shallow man-made lakes were built into this interchange area to provide some replacement for the reclaimed river and to produce reflecting pools. The lakes performed a separate engineering function in that they receive and store fresh ground water, pumped to the area from the Hamilton Interchange and then used for reticulating the lawns and trees.

Landscaping

By preplanning the whole of the interchange planting programme, a nursery was developed in South Perth at the very commencement of earthworks. Many hundreds of trees were planted and established in specially designed containers so that by the time the interchange was ready to accept planting, the trees and matured and grown to heights of up to 6 metres.

The trees were moved to the Narrows on specially built transporters and placed in prepared ground, providing some early maturity to the landscaping. Couch grass was used for the balance of land areas being capable of survival in a salty environment and able to accept minimal watering. The dry summer colouring is compatible with other public areas throughout the city. However, the interchange area is fully reticulated and now has a much more formal appearance than was originally proposed, with an extensive and closely mown grassed area.

Miscellaneous Works

Separate contracts were arranged for lighting, reticulation, water supply, signs and sign gantries to complete the interchange.

Construction Resources

The building of the interchange, which includes five road bridges, two footbridges, three subways and the park areas, was completed by a blend of private and public enterprise—all structural work being contracted and the balance undertaken by the Department's own resources.

The interchange was formally opened on November 30 1973, some 19 years after the first work on reclamation for the Narrows Bridge started. It had proved to be an immense task because of the difficult site conditions. It was a large drain on the Department's resources, but the end result had been brought to a satisfactory conclusion. The interchange, like the Narrows Bridge, was a very vital part in the new freeway system.

MITCHELL FREEWAY

The Central Section—Mount Street to Murray Street

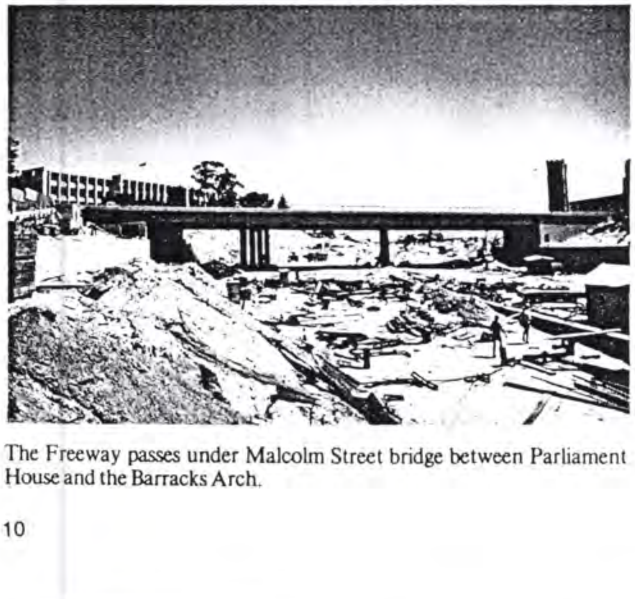
The design of the Central Section of Mitchell Freeway from Mount Street to Murray Street began in 1961 under the supervision of De Leuw Cather and Co., Consulting engineers, of Chicago. This company provided the expertise in freeway road design which was lacking in Australia at that time. They also gave advice on the continuity of elements of the design, which was important aesthetically to maintain unity in the overall design. Subsequently De Leuw Cather and Co were also involved in the design of Stages 2 and 3 of the freeway.

Construction commenced in 1966 which was concurrent with the start of major earthworks in the Narrows Interchange area. The work which was completed in 1968 provided bridges crossing the freeway at Malcolm and Hay Street, and a freeway bridge over Murray Street.

While physically one of the shortest stages of the freeway construction, this section proved to be one of the most difficult. Passing through the centre of built-up Perth, almost every known underground service was severed, requiring an intense programme of service relocation before construction could commence.

To minimise the need for, and cost of, land acquisition, extensive use was made of high retaining walls throughout this area and special consideration was given to concrete finishes. Trials were conducted, off site, of special textures and finally the sand blast treatment adopted. It has the benefit of simple removal of graffiti with little visual alteration.

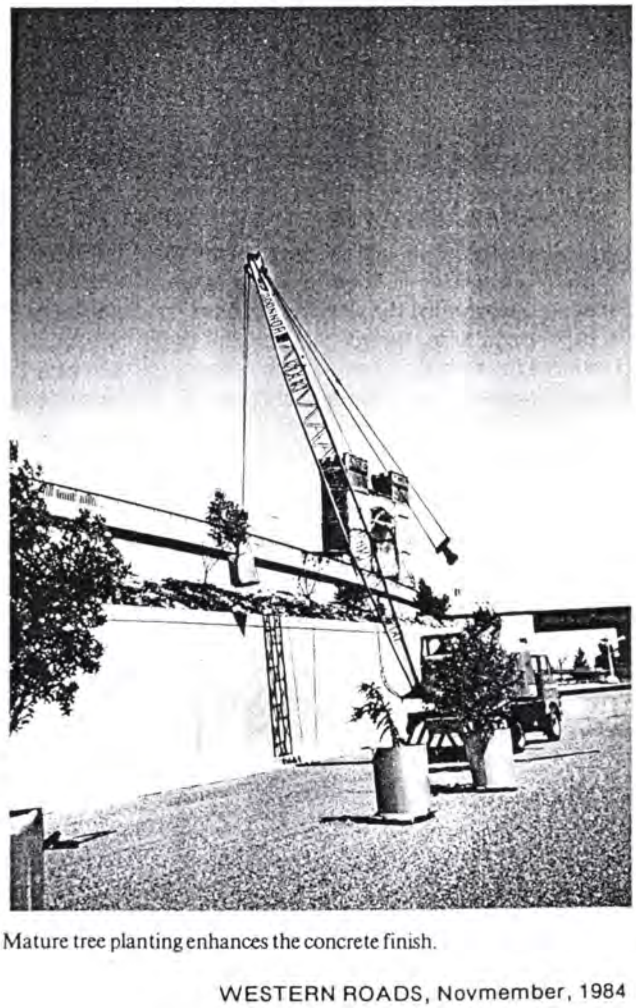
Mention must be made here of the Barracks Arch controversy. The Government of the time wished demolition of the Arch to provide views of, and from, Parliament House to St George's Terrace, but public outcry forced the Government to change its views, and by alternative design, it was possible to retain the Arch. The removal of the Barracks' wings to preserve the Arch required considerable underpinning and hand brickwork to maintain its aged appearance.



The Freeway passes under Malcolm Street bridge between Parliament House and the Barracks Arch.

A temporary connection from the Central Section to roads in the Narrows Interchange was provided making use of Bailey Bridging over Mounts Bay Road. Thus at the end of the first decade after the opening of the Narrows Bridge, a connection was provided via the ramps of the Central Section into the street system in West Perth.

The central section of freeway between Mount and Murray Streets being linked to the Narrows.



Mature tree planting enhances the concrete finish.

Hamilton Interchange

The Wellington Street bridge marks the beginning of the Hamilton Interchange.

The developed Hamilton Interchange including the busway bridge in the central foreground.

The Hamilton Interchange was the next section of freeway to be started. It was constructed in the years 1969 to 1972 and coincided with the final stages of the Narrows Interchange. Its construction followed as a continuation of the Central Section, extending it northwards over Wellington Street and the railway line. It also included bridges over both James and Aberdeen Streets and when the first stage was opened in November 1971, it provided grade separated access via the freeway for the first time for Perth's northern suburbs with connections to Sutherland and Charles Streets. The structures were completed in a stage from in two contracts to provide part of the final development of the interchange. On and off ramps providing access to Wellington Street and the connection of the future City Northern Bypass are still to be built.

The site consisted of soft, poorly graded sands requiring densification which was undertaken by a Frankipile technique so that conventional structures could be built without the use of piling. Of interest, work in this interchange yielded the first experience with Perth's northern swamp areas and the incidence of reclaimed peaty areas previously used for market gardens and other developments.

Work on the structures and roads in the interchange was completed in October 1972. The work on landscaping continued after this date.

MITCHELL FREEWAY STAGE 2

Hamilton Interchange to Vincent Street

A start was made in February 1974 after completion of Hamilton Interchange, on the extension of the freeway to a temporary termination at Vincent Street in Leederville. This stage of the freeway totalled 1.6 kilometres in length and included the following—

- A large curved high level bridge to connect northbound traffic to Charles Street.
- The first of ultimate twin bridges crossing Loftus Street over the freeway.
- A pedestrian bridge over the freeway at Oxford Street and a subway under Loftus Street.
- Many alterations to the local street systems, mainly the diversion of Cambridge Street to the West Perth Subway and the removal of Charles Street.

A special feature of this stage was the construction of a bridge in the northbound carriageway providing solely for rapid transit facilities. This bridge allows buses to travel directly from the new central city bus station via Roe Street to the northbound freeway.

Another aspect of interest in this stage was the use of what will ultimately become the southbound carriageway of the freeway, for travel in both directions. Traffic is separated by a solid steel beam to provide a narrow median. Future freeway shoulders were used to form part of the freeway pavement in this stage. Plans allow for duplication when traffic conditions dictate.

Mention must also be made to the severe impact of this work on Leederville. The freeway cut through the original subdivision requiring the acquisition and demolition of both residential and industrial properties as well as cutting streets.

Stage 2 was opened in March 1976 allowing traffic access to Vincent Street and Leederville.

MITCHELL FREEWAY STAGE 3

Vincent Street to Hutton Street

Stage 3 of Mitchell Freeway passing between Lake Monger and the Velodrome traverses landfill and peat.

Work on Stage 3 followed quickly after the conclusion of the previous stage. In order to avoid as much development as possible, the route for Stage 3 of the freeway passed over several former wetlands, two areas of sanitary landfill at Vincent Street and along the frontage of Lake Monger, and also through peat-filled swamps at Powis Street and north of Scarborough Beach Road.

The nature of this site required a large degree of preliminary work to improve the ground so that it was suitable for construction purposes before a contract for construction could be let. Techniques were developed for the consolidation of both peat and landfill by surcharging with large sand embankments. Once the desired consolidation had been achieved the surplus sand was removed for re-use elsewhere in the project. The work required the importation and re-use of over half a million cubic metres of sand.

When site improvement had developed to a sufficient degree, tenders were called for the construction of permanent works on the freeway in 1976. These works provided freeway bridges and associated ramps at Vincent Street, Powis Street and Scarborough Beach Road.

As a continuation of the public transport facilities built during Stage 2, the freeway ramps at Scarborough beach Road are restricted to buses and taxis only, and provide rapid access to the Innaloo bus terminal in Odin Road. The use of future southbound carriageway, divided by a central beam for two-way traffic was continued throughout Stage 3 to MacDonald Street and the connection from this point to Hutton Street was made, using future frontage roads on each side of the freeway.

Special features of this stage included:

- The use of an open graded asphalt surfacing to produce better road drainage and markedly improve skid resistance for high speed traffic.

- The excavation of peat and garbage from bridge locations to provide suitable foundations. The excavated material was used in the development of Heirisson Island.

- Pedestrian footbridges were provided at Leeder Street and over Powis Street for use by school children attending the nearby schools in Dodd Street.

Stage 3 was completed in June 1978 and it won the Western Australia Engineering Excellence Award presented by The Institution of Engineers, Australian for that year.

MITCHELL FREEWAY STAGE 4

McDonald Street to Erindale Road

The freeway continued to follow a route passing through peat swamps and sanitary landfill areas. In this case, both were far more extensive than previously encountered and peat compression techniques were again successfully adopted while garbage was relocated where possible. A new technique of handling garbage where relocation was not possible, using dymanic consolidation was developed. This technique involves a high degree of impact-consolidation such that the garbage is both compressed and subject to stresses which will exceed those likely to be encountered by operating traffic. These works were extensive in nature and were completed over a period of 18 months.

Actual construction started early in May 1982 and in various stages provided for road bridges over the freeway at Hutton Street, Cedric Street and Karrinyup Road. A footbridge provided at Hector Street made use of a steel arch to produce a different and pleasing design.

The number of heavily trafficked roads passing through the site required the Department to undertake difficult connections of newly completed works to local roads. These works usually commenced at midnight Friday night for re-opening to public prior to the Monday morning peak traffic, and involved treble shifting, work under floodlights and the use of a high degree of engineering judgment.

The work, an impressive array, included:

- The acquisition of 134 properties.

Surcharged loading for the freeway across the Hertha Road Swamp.

The wide central median of the freeway provides for widening and a future rapid transit facility.

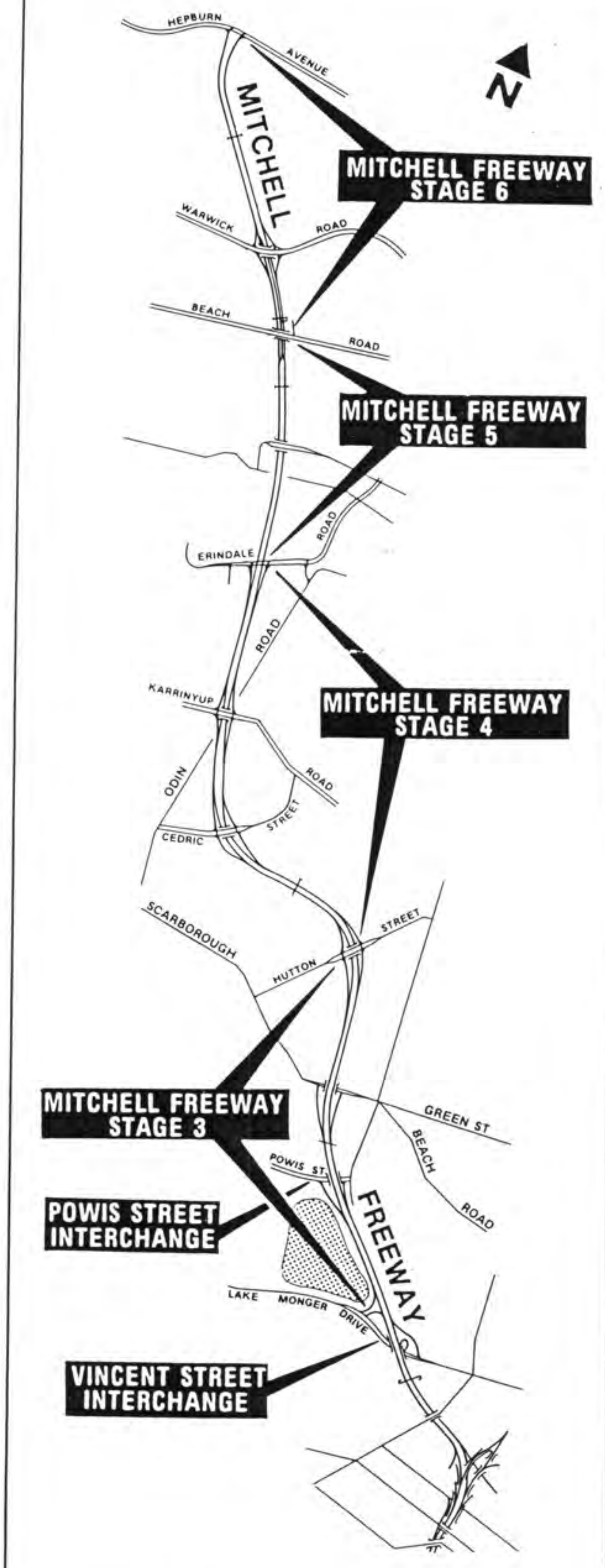
- The use of 1,750,000 cubic metres of fill.

- The relocation or reconstruction of water, electricity, gas, telephone, and drainage mains.

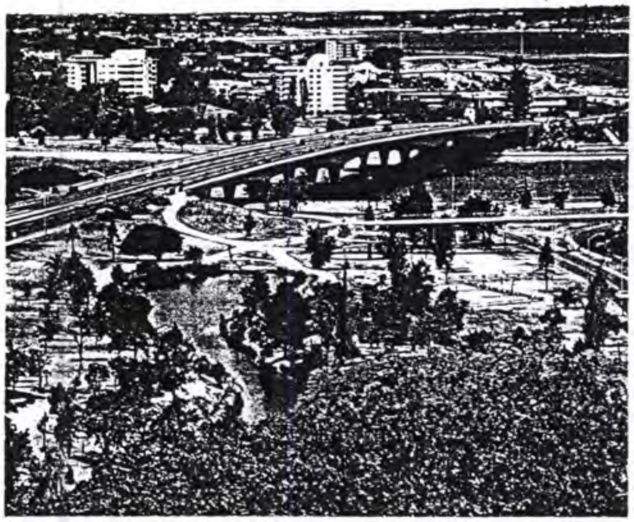
- A diversion or reconstruction of local street systems by Stirling City Council.

- The connection of new facilities to the streets by the Department.

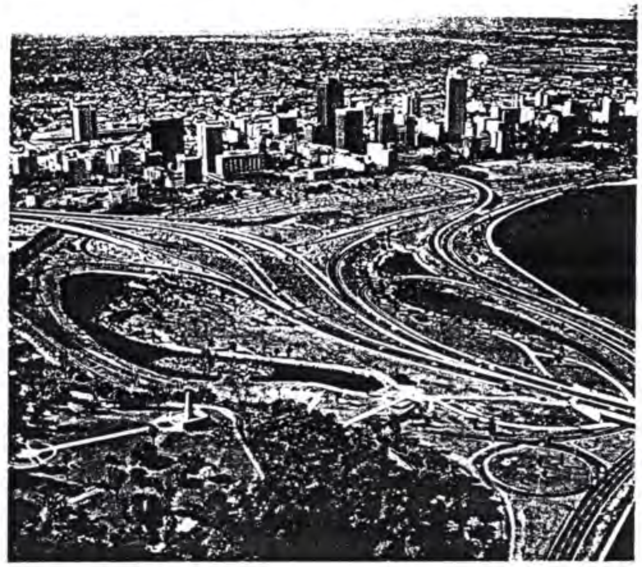
While not specifically included in Stage 4 of the freeway, advantage of the site and materials enabled a start of



VINCENT ST TO HEPBURN AVE



Pedestrian access to the landscaped interchange is catered for by the connecting paths, bridges and subways.



The completed interchange.

The interchange at night.

One of the subways at the Narrows Interchange.

Stage 5 to be included in these works, with the provision of a bridge over the future freeway at Erindale Road. Pedestrian facilities were catered for during this stage by footpaths on all bridges, a footbridge at Hector Street and Civic Place to provide access across the freeway for local residents and school children attending Birralee Primary School, and twin underpasses also to form a cycleway at Erindale Road.

Allowance for a separate public transport system was made throughout this stage by the provision of an extra wide median and a future bus terminal north of Karrinyup Road.

The freeway was opened first to Karrinyup Road in December 1983 and then to Erindale Road in September 1984.

KWINANA FREEWAY

Narrows Bridge to Canning Highway

When first opened in 1959 to provide access to the Narrows Bridge, the freeway provided two lanes in each direction and all traffic connections were at grade. With traffic growth and further development of the freeway system to the north and south, a number of improvements were made to match the increasing demands on the original construction.

South Perth Interchange

The on and off ramps to South Perth constructed with the Narrows Bridge were on an alignment suitable for

The South Perth Interchange.

The freeway link between Hamilton Interchange and Vincent Street.

An urban forest emerges alongside the freeway.

Hutton Street bridge was connected to the street system during a weekend shift.

traffic at the time, but always acknowledged to be in a temporary location. By 1975, when traffic on the Narrows Bridge was averaging 85,000 vpd, the merging of entering flow to the freeway caused serious congestion on the Narrows Bridge and it had become necessary to construct the permanent ramps without delay.

An interchange was designed on the previous alignment of Judd Street in South Perth. It included a bridge curving through 87° spanning the freeway and the provision of an unrestricted free slip on to the freeway. The interchange work required the demolition of a footbridge at the foot of Judd Street and its replacement at Hardy Street to maintain access to the river foreshore. Particular care was taken with the aesthetics of both bridges including extensive architectural advice because the bridges intruded into the views from nearby residences in South Perth. Their length was increased and the footbridge built with graceful lines adding to cost, but producing a pleasing result. The interchange was lit by high mast lighting.

The interchange which was opened in December 1976, caused some local construction problems. Construction clearances were very small and purpose-made height warning devices were used to reduce the risk of over-height vehicles striking bridge formwork and thus causing a collapse. The first of these consisted of a gantry across the freeway from which were suspended empty drums to provide a noise on impact and the second used light sensors set at vehicle operating heights

and operating flashing lights and illuminated signs.

Demolition of the footbridge required the closing of the freeway from Canning Highway for public safety, and for this reason, the bridge was demolished between the hours of midnight Friday to 6 am Monday morning.

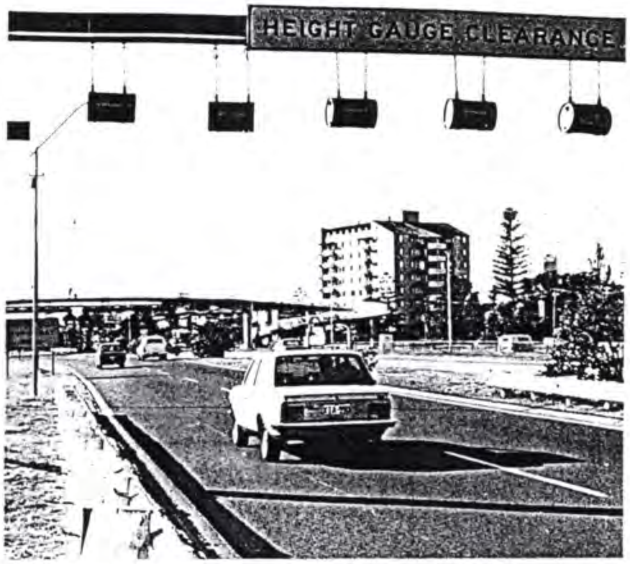
Canning Interchange

The next problem to be solved was the congestion arising from traffic on Canning Highway, the Canning Bridge and Manning Road, at the southern most end of the current freeway. During the period 1978-79, two bridges were built to carry Canning Highway over the freeway and a bridge provided to give direct connection from Manning Road to both the freeway north and Canning Highway. Again, because of its sensitive location, particular care was taken to minimise obstructions with a view to landscaping the area and to maintain access to the waterfront. Opportunity was taken during this construction to construct new permanent on and off ramps in readiness for the early construction of the southern extension of the freeway.

Kwinana Freeway Widening

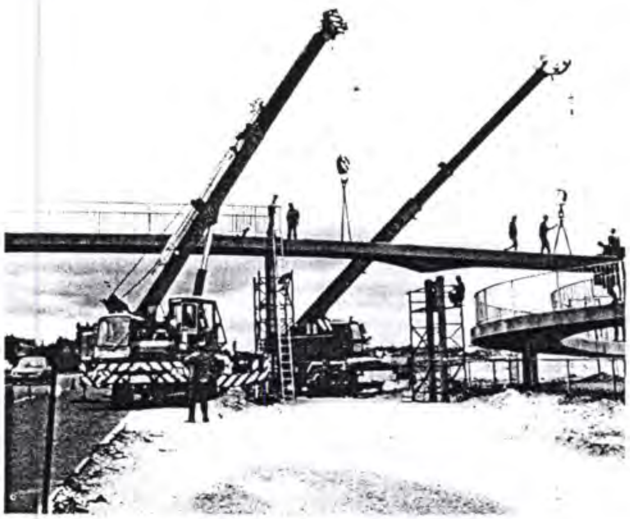
To cater for the additional traffic that would use the freeway from the south following completion of the extension to South Street, the existing Kwinana Freeway was widened under traffic to three travel and one break-down lane in each direction. Opportunity was taken during the widening to realign and reconstruct, where necessary.

An interesting engineering feature of this work was the task of both widening and lifting the three footbridges at Como. This work provided significant savings when compared with demolition and replacement and was completed without interruption to traffic use. A new footbridge was provided near Cale Street.



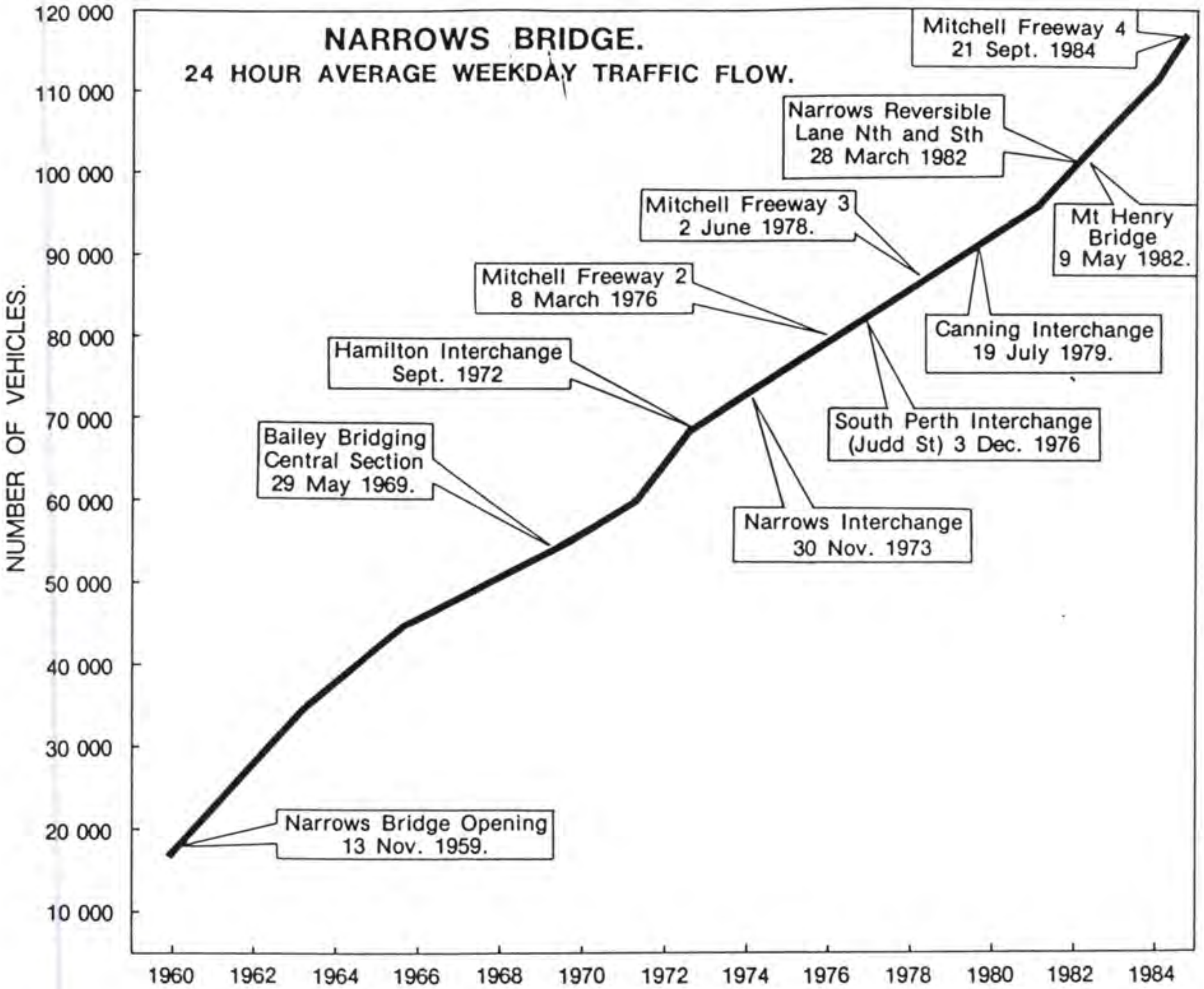
This system was a noise deterrent to overheight traffic.

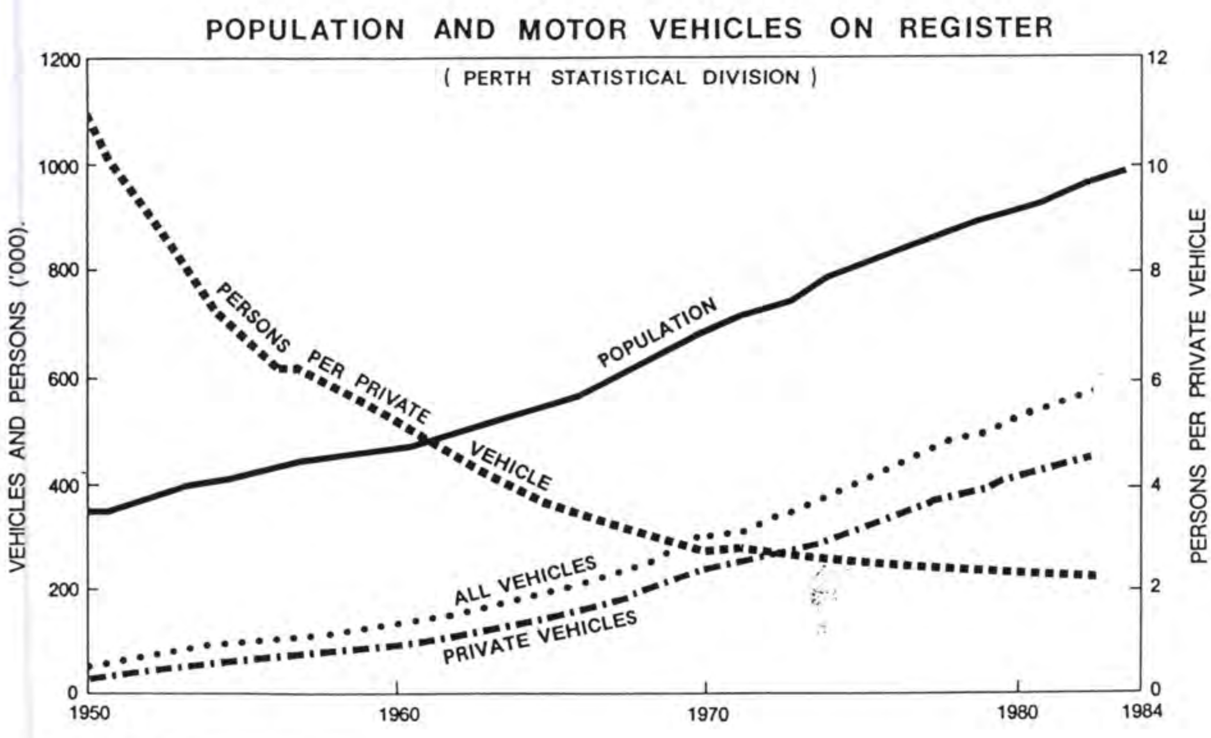
Twin bridges carry Canning Highway across the Kwinana Freeway.



Raising one of three footbridges utilising a prefabricated steel section.

A raised footbridge spans the widened Kwinana Freeway.


NARROWS BRIDGE.
24 HOUR AVERAGE WEEKDAY TRAFFIC FLOW.
NUMBER OF VEHICLES.
120 000
110 000
100 000
90 000
80 000
70 000
60 000
50 000
40 000
30 000
20 000
10 000
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
Narrows Bridge Opening 13 Nov. 1959.
Bailey Bridging Central Section 29 May 1969.
Hamilton Interchange Sept. 1972
Narrows Interchange 30 Nov. 1973
Mitchell Freeway 2 8 March 1976
South Perth Interchange (Judd St) 3 Dec. 1976
Mitchell Freeway 3 2 June 1978.
Canning Interchange 19 July 1979.
Narrows Reversible Lane Nth and Sth 28 March 1982
Mt Henry Bridge 9 May 1982.
Mitchell Freeway 4 21 Sept. 1984


POPULATION AND MOTOR VEHICLES ON REGISTER
(PERTH STATISTICAL DIVISION)
VEHICLES AND PERSONS ('000).
PERSONS PER PRIVATE VEHICLE
1200
1000
800
600
400
200
0
12
10
8
6
4
2
0
1950
1960
1970
1980
1984
PERSONS PER PRIVATE VEHICLE
POPULATION
ALL VEHICLES
PRIVATE VEHICLES

Narrows Bridge Reversible Lane

The reversible lane on the Narrows Bridge improves peak hour traffic flow.

Growth of traffic on the Kwinana/Mitchell Freeway system was causing increasing congestion on the Narrows Bridge in the seventies. Concurrent with the widening and extension of the Kwinana Freeway, the Narrows Bridge was widened from six lanes to seven. This was achieved at the expense of the downstream footpath and required some strengthening of the bridge. With seven lanes, it was possible to arrange that the central lane was reversible so that four lanes could operate towards the City in the morning peak and four lanes away from the City in the evening peak. It is interesting to note that when the Narrows Bridge was designed, it was based on a forecast of 6,000 vph. The actual peak hour traffic prior to the reversible lane being introduced was 9,600 vehicles. At this stage, the total daily traffic on the bridge was almost 100,000. Now that the peak lane is operating, peak hourly flows have reached 13,300 and the daily flow is up to about 120,000 vpd.

The reversible lane is operated by a microprocessor based controller located in the abutment of the Narrows Bridge. It is programmed to provide the correct sequence of barrier operation and sign change and has a built-in fail-safe malfunction warning capacity.

The barriers consist of lightly constructed arms fitted with reflectorised chevron boards and flashing lights which operate when the barriers are moving. The changeable signs consist of an endless roller blind which is electrically operated to expose alternative messages.

Canning Highway to South Street

Southern extension of Kwinana Freeway looking towards the Cloister Avenue boat bridge, with Mount Henry bridge in the background.

The Leach Highway Bridges looking towards South Street.

The extension of the freeway southwards from Canning Highway between 1979 and 1982 again involved controversy because of its location on the Canning River foreshore and the necessity for further reclamation. A small area of reclamation immediately south of Canning Bridge required particular protection to prevent scouring. The river wall was faced with limestone for appearance and at the same time to ensure that it could be readily climbed by anyone wading in the river. In the vicinity of Edgewater Road, a larger area was necessary and particular care was taken to cover the river bed adjacent to the new shoreline with dredged material from the river bed in the reclaimed area, in an attempt to re-establish the original condition as closely as possible.

This section of the freeway involved a variety of structures, all of which were designed by Main Roads Department staff and constructed by contract. At Cloister Avenue, a curved bridge was built to provide access to a boat launching ramp on the river foreshore. At Edgewater Road, a bridge has constructed to provide pedestrian access. Road bridges were provided across the

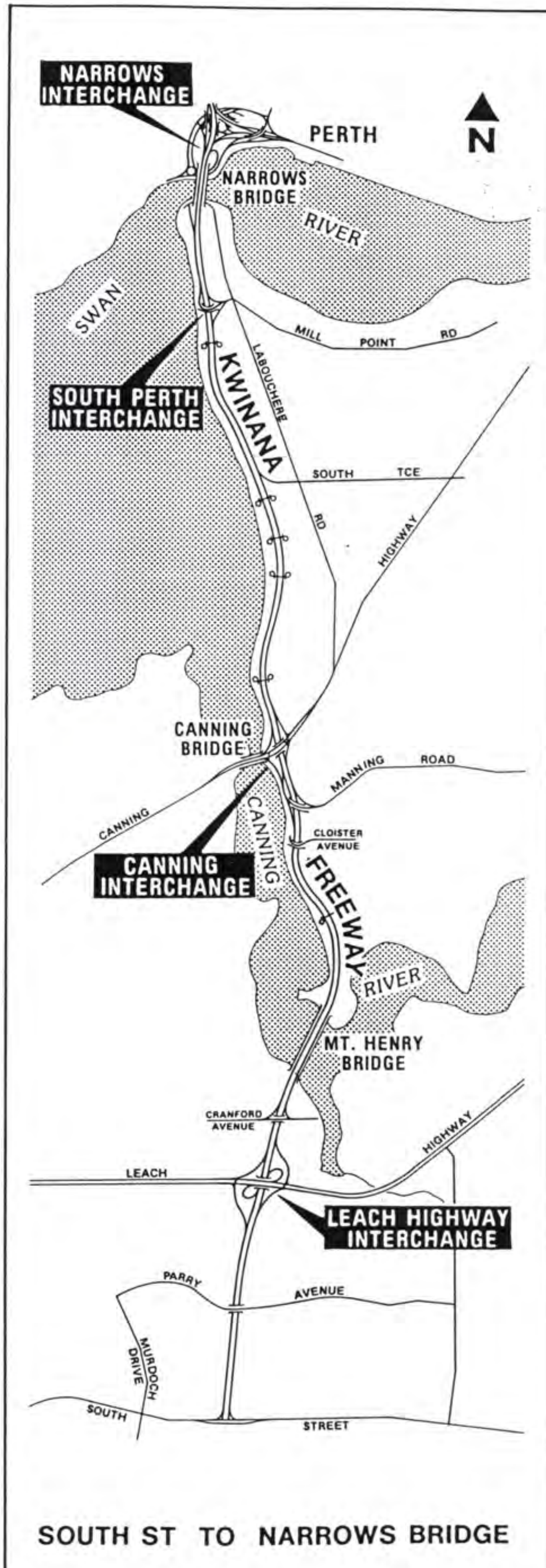
The Cloister Avenue boat bridge provides access to the foreshore and cycleway-walkway.

The Leach Highway interchange.

freeway at Cranford Avenue, Leach Highway and Parry Avenue.

The major feature of the freeway work was the construction of the Mt Henry Bridge over the Canning River, the longest road bridge (660 m) built in Western Australia. The Contractor for the bridge was J. O'Clough and Son Pty. Ltd., the same Contractor as was associated with Christiani and Nielsen in the construction of the Narrows Bridge between 1957/59. The bridge carries six lanes of freeway traffic with two dual purpose footway/cycleways below road level protecting users from the weather and traffic noise. The bridge also carries a multitude of services within its core. For the first time in Western Australia a cable-stayed truss was used to erect precast concrete segments more economically than using falsework supported by piles.

Road construction to the north of Mt Henry Bridge was undertaken mainly by contract and by the Department's own staff to the south. On the southern side, the



freeway was depressed to minimise its effect on the surrounding community. This involved construction below the original water table in the area, requiring particular attention to drainage.

Care was taken throughout the work to conserve the original topsoil and this was spread over the new surface when earthworks were complete to encourage the regeneration of natural vegetation. The appearance of the freeway today is enhanced by the success of the technique and also by the extensive planting (over 100,000 trees) that took place.

Specially designed river drainage outfalls were built to keep the foreshore undisturbed. During the works, every effort was made to preserve all natural vegetation possible and special mention should be made of the stand of paperbark trees near Cloister Avenue, which was fenced off to prevent any intrusion by construction plant.

The final phase of the work involved the development of a footway/cycleway extending from Cranford Avenue in the south to Canning Bridge and along the previous section to the Narrows Bridge. The path was threaded through stands of native trees and linked to all footbridges to form a continuous facility along the water's edge. The southern extension was formally opened in May 1982.

STIRLING BRIDGE

The original Metropolitan Region Scheme did not allow for a bypass for Fremantle. During the late sixties the Council in conjunction with the Metropolitan Region Planning Authority and the Main Roads Department developed the concept of the Fremantle Eastern Bypass which was incorporated in the Scheme in 1973.

An essential part of this plan was the construction of a new bridge over the Swan River some 400m upstream from the timber Fremantle traffic bridge.

Stirling Bridge over the Swan River at Fremantle.

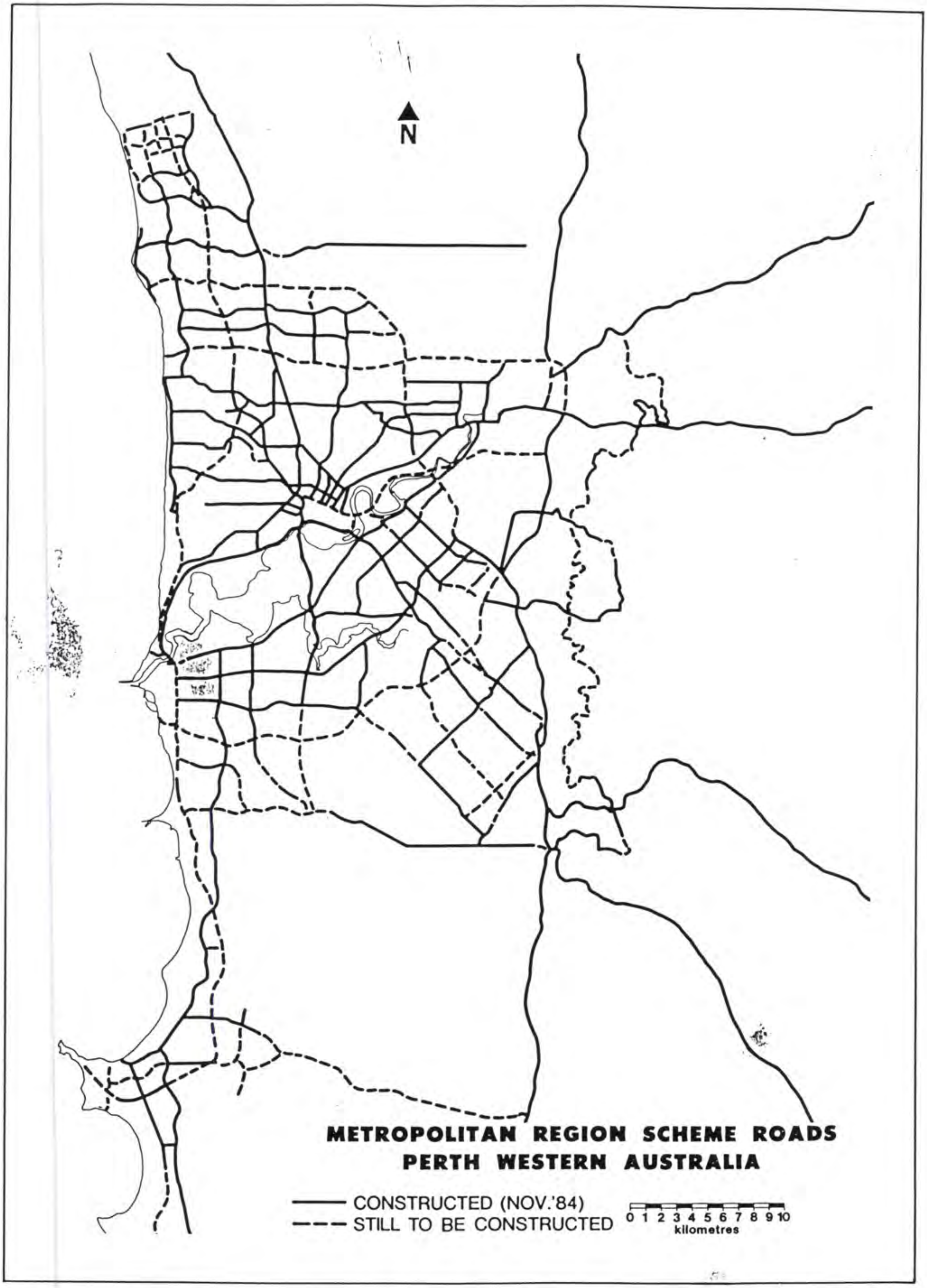
Mount Henry bridge looking north along Kwinana Freeway.

Because of the historic importance of the site and the 10 m difference in level each side of the river, the design of this bridge posed an aesthetic challenge. The solution adopted by Consultants Maunsell and Partners was a bridge of deceptively simple appearance but actually complex design. Each bridge span varies in length and the deck thickness increases continuously from north to south. These features ensure the overall aesthetic balance of the design and also that the bridge fits naturally into the location. This effort was rewarded by two awards, the Engineering Excellence Award by the Association of Consulting Engineers Australia and the Award of Excellence in Concrete by the Concrete Institute of Australia.

The bridge was completed over a 2 year period at a cost of $2.5 million. It is 415 m long and has precast segmental prestressed concrete boxes forming a superstructure supported on concrete filled steel piles.

The approaches to the bridge were built by the Department and included connections to Stirling Highway and Tydeman Road on the north and connection to Canning Highway on the south, with temporary connections to King and Silas Streets to give access to Leach Highway. The project was opened in May 1974 after a construction period of less than two years.

All these works involved the demolition of dwellings because the road system had to be constructed through long established areas. Although opened in 1974, the design of the approach from Leach Highway is only now being finalised in readiness for construction in the near future. Land acquisition and property demolition for the new road is now complete.


N
METROPOLITAN REGION SCHEME ROADS
PERTH WESTERN AUSTRALIA
CONSTRUCTED (NOV.'84)
STILL TO BE CONSTRUCTED
0 1 2 3 4 5 6 7 8 9 10
kilometres

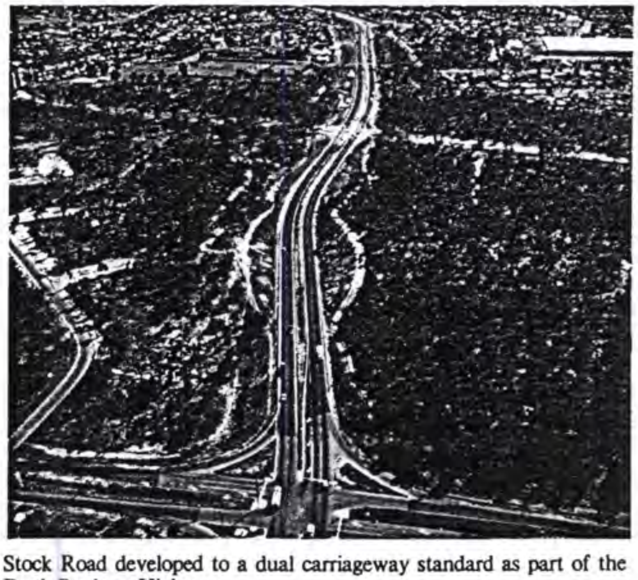
THE MAJOR ROAD SYSTEM

At the time the Narrows Bridge was built, the Main Roads Department had responsibility for the major roads radiating from the City. The last 25 years has seen the further upgrading and development of this system. In some cases, such as Canning and Stirling Highways, maintenance and minor improvements have largely sufficed to meet the demands being made on the roads though some major work has been undertaken over short lengths, e.g. the duplication of Stirling Highway past the University of WA. In other cases, more major works have been necessary to enable roads to cope with the increasing demand. This included such work as the upgrading of the Albany, Canning and South Western Highways. Elsewhere completely new roads have been developed in accordance with reservations in the Metropolitan Region Scheme. The larger of these works are described in the following section.

DEVELOPMENT OF EXISTING ROUTES

Bunbury Highway

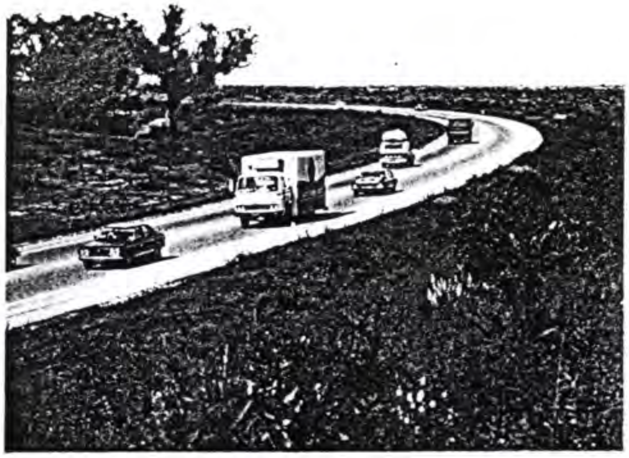
The fifties saw the development of the oil refinery and the new town of Kwinana confirming this area as the major industrial region of Perth. These works were soon followed by a steel works, fertilizer factory, alumina refinery, power station and in later years a nickel smelter. These major industries were supported by small businesses.



Stock Road developed to a dual carriageway standard as part of the Perth-Bunbury Highway.

When the first major development occurred the area was served by a system of two lane semi-rural roads poorly equipped to cater for industrial traffic demands. The progressive development of the major road system, shown in the Metropolitan Region Scheme, was urgently needed and this work started in the sixties with the development of Stock Road to modern standards. The road not only services the industrial area of Kwinana but also caters for the growing South West Corridor of the region. It must also meet the very heavy holiday demands placed on this coastal route.

With the completion of the second carriageway south of Rockingham, the route is now a dual carriageway 46 kilometres long, subject to access control over much of it, from Leach Highway, Willagee, south to the approaches to Mandurah outside the Metropolitan



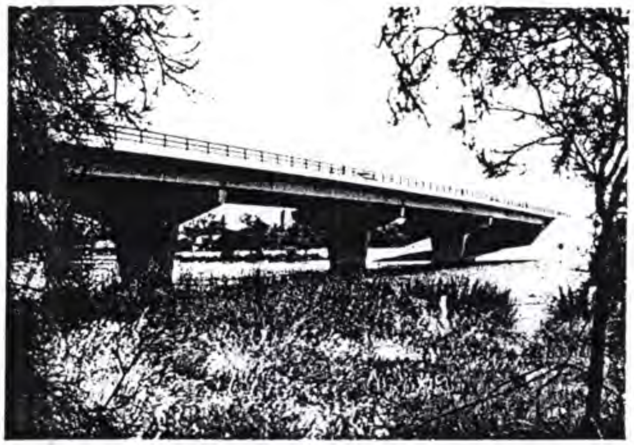
Ennis Avenue extension, part of the Perth-Bunbury Highway.

Region. The highway development involved the extension of Stock Road on new alignment to join Rockingham Road in Munster and the provision of a new road southwards from Rockingham west of Lake Cooloongup and the original Mandurah Road, to serve the developing sub regional centre. Three railway lines have been bridged and allowance has been made in the design for bridges at major intersections, if ever required. Bridge and some roadwork was undertaken by contract but most of the pavements were built by the Department's own workforce.

Leach Highway

The Metropolitan Region Scheme made provision for the high class road between the port of Fremantle and the standard gauge rail head at Welshpool. The Commonwealth decision to complete the Kalgoorlie-Welshpool standard gauge rail line added extra incentive to construct this road.

Work started in 1967 in the Melville area with the upgrading of High Street and was completed through to Hardey Road in 1978. Upgrading is continuing as necessary and the latest addition was in 1980 when the bridge over Albany Highway was opened to traffic.



Shelley Bridge carries Leach Highway over the Canning River, replacing the old bottleneck timber bridge at Riverton.

Leach Highway crosses Albany Highway via a modern bridge.

Much of the work involved the development of the existing street system, but some completely new alignments were chosen at Shelley Bridge and through Bentley and Welshpool.

The 22 km dual carriageway includes a number of bridges, the first being the Ewing Street bridge over the railway at Welshpool. A distinctive feature of this bridge is the use of a technique known as Sculpcrete to provide an attractive finish to the concrete abutment walls. The bridge also incorporated the first use of partially prestressed concrete in Australia, the use of which in this and many other bridges since has resulted in substantial cost savings.

The old route through the City of Canning used the timber bridge over the Canning River at Riverton. The new route required a high standard crossing of the river which lead to the design of the Shelley Bridge. Located over a waterway used extensively for canoeing, swimming and fishing, it was essential to create an open design with no restriction on river front access. The visual barrier of the bridge and its approaches was deliberately softened in design by the use of long spans, uncluttered lines and the type of pier employed. The abutments were also set wel back to allow the visual continuity of the river and its banks to remain unbroken.

The design adopted for Shelley Bridge allows for its duplication immediately alongside the existing structure. This work will be undertaken when the demand for the additional road space increases. The bridge carries three very large water supply pipelines between its girders.

When Shelley Bridge was opened in March 1978, it completed the dual carriageway in Leach Highway removing a serious point of congestion. The bridge which is 230 m long and of segmental construction cost $2.8M.

When works started on this road the route consisted of a number of local streets of different names plus many secitons of new road. In 1970, as recognition of his contribution towards the Metropolitan road system, the route was named Leach Highway after the late Mr J.D. Leach,CommissionerofMainRoads1953—1964.

Sections of Leach Highway are subject to access control, however, properties with direct frontage remain in the older areas. Currently, it has three lanes in each direction over much of its length.

Great Eastern Highway

Over the years, major upgrading took place on three sections of Great Eastern Highway. Progressive work between 1957 and 1975 provided a dual carriageway from the top of Greemount Hill through to Mundaring, a distance of 9 km. Work was also completed in 1975 on the provision of a dual carriageway through Guildford via James and East Streets and in 1978 reconstruction of the section across the river flats between the Causeway and Rivervale was completed. This latter work coincided with the construction of the Interchange at the eastern end of the Causeway.

Perth City Council has subsequently carried out extensive landscaping in the area providing a most attractive entry to the City.

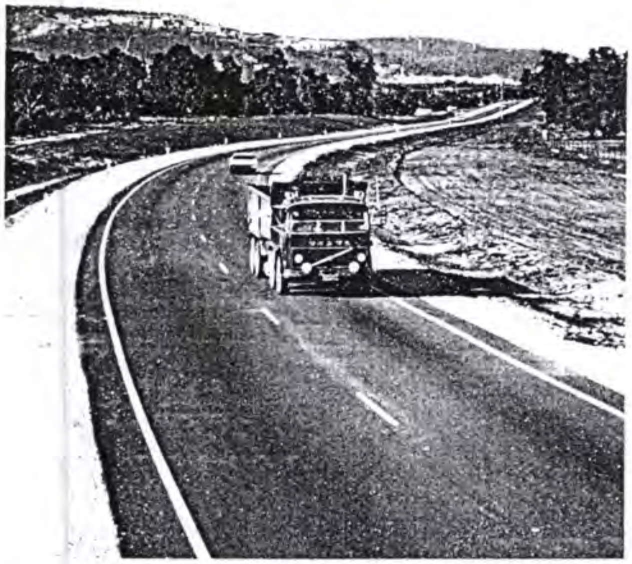
Wanneroo Road

Wanneroo Road which is under the control of the Main Roads Department northwards from Main Street was the subject of intense work in the latter seventies, particularly to complete a dual carriageway for the 10 km from Main Street to the northern end of the Wanneroo Townsite.

PROVISION OF NEW ROUTES

Beechboro—Gosnells and Roe Highways

The decision by the MRD in the 1950's to resume rural land for the future major road system was to bear fruit some 25 years later. In 1979 the decision was made to start work on the Beechboro-Gosnells Highway from Gosnells to Forrestfield. In the first instance this route was to combine with the proposed Roe Highway to form a route from Gosnells to Midland along the foothills of the Darling Scarp.

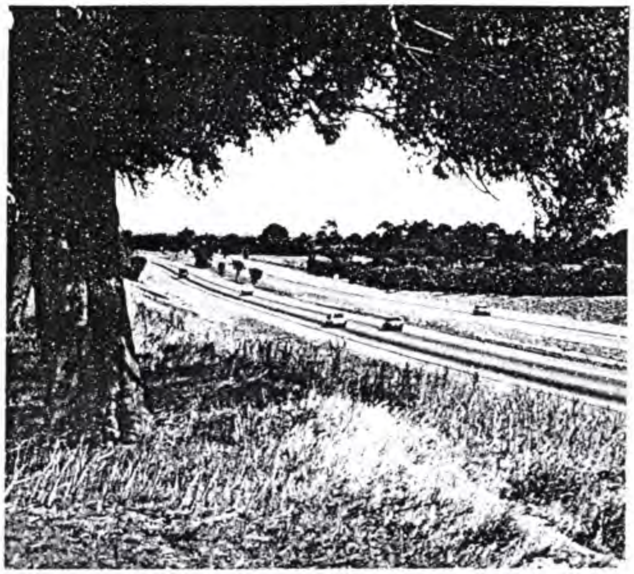


Traffic on first stage of the foothills route, near Gosnells.

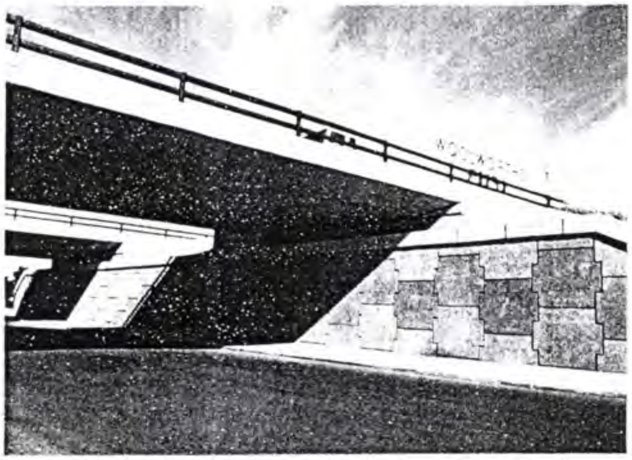
This 23 km route has just been completed to Great Easterrl Highway at Midland and it is proposed that further work will be undertaken to extend the highway through to Great Northern Highway. The road has been built to high standards and has the major benefit of providing a route for commercial traffic between the major country radial routes leading out of the region. When the project is complete to Great Northern Highway all country highways to the south, east and north will be linked by a road that avoids all residential areas and provides a high speed, safe road link.

Many bridges have been built on the road and the project has seen the first use by MRD in Perth of a new technique known as reinforced earth. The process was used on the Maddington Road, Clayton Street, and Rason Parade bridges. Reinforced earth (or la terre armee) was invented by Henry Vidal in France in the early 1960's. It is a construction process whereby selected earth fill and metal reinforcing strips are combined to form a composite material. In the right conditions it has a distinct cost advantage and can be used where there are space limitations for the construction of extensive embankments.

Recently, work was undertaken to extend the Beechboro-Gosnells Highway to join Leach Highway. This work provided a temporary railway crossing at



Traffic on Roe Highway.



Reinforced earth abutment at the Maddingtòn Road bridge on Beechboro-Gosnells.

Forrestfield and connection to Hardey Road. Work designed by Consulting Engineers Bruechle, Gilchrist and Evans is in progress on the construction of four bridges to carry both carriageways of the highway over the railway lines at Forrestfield. Once again a technique new to Australia is being used in that the bridge deck is being cast on the approach embankment behind the abutment and progressively launched across the opening as additional sections of deck are cast.

On the north of the river, a further length was completed in 1984 between Guildford Road and Morley Drive. Work is currently in progress between Hardey Road and Great Eastern Highway.

With the introduction of the Commonwealth Government's Bicentennial Road Development Programme Beechboro-Gosnells Highway will be developed between Albany Highway, Gosnells and Morley Drive over

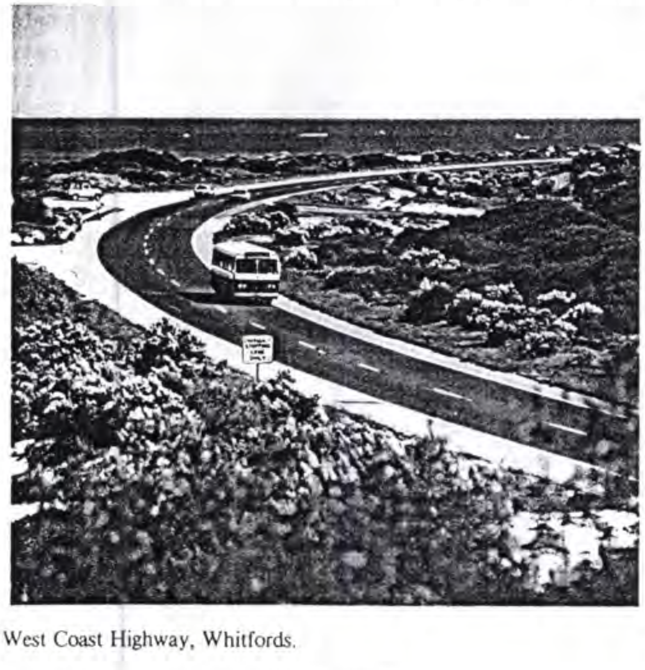
Beechboro-Gosnells Highway near Broun Avenue.

it full length and thus within the next few years it will provide a second high class north-south road facility serving the Metropolitan region.

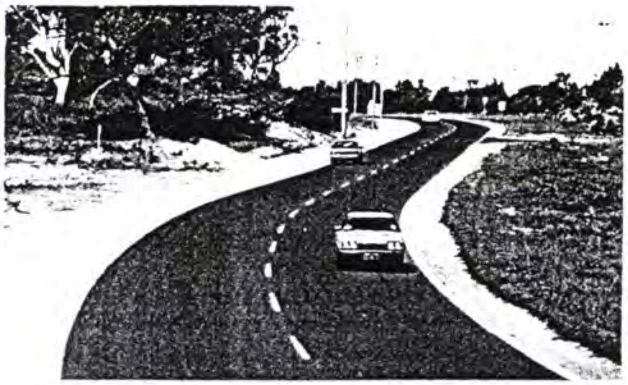
The Northern Suburbs

By the late 1960's the rapid population growth in the region was placing a strain on the supply of suitable urban land. As a result of this pressure land prices escalated rapidly. To overcome this problem the Government combined with the Wanneroo Shire and a number of large land owners to release some 3500 acres of urban development. The funding of the road construction was also a joint effort.

The Shire of Wanneroo was not equipped to handle such a large scale development within its area and the Department provided the resources to plan, design and construct the major road system for the development. The development agreement led to the construction of Marmion Avenue, Whitfords Avenue, Ocean Reef Road and the new length of West Coast Highway. These



West Coast Highway, Whitfords.



Whitfords Avenue, near Whitford Shopping Centre.

major roads were to provide the framework that allowed the development of some of the most modern residential suburbs in Perth. At the same time as these roads were being developed the balance of the Northern Corridor was planned in detail and provision made for the other major roads that would eventually be required. As a result of this planning future extensions of the Mitchell Freeway will be able to be constructed without the need to purchase private land.

Recently, the Department has been similarly involved in the construction of Joondalup Drive and Hodges Drive to serve the future sub-regional centre.

OTHER WORKS

In the 25 years since the opening of the Narrows Bridge, many other major projects have been undertaken on roads throughout the Metropolitan area. Several examples follow.

The Department was involved in the construction of dual carriageways in Thomas Street and Winthrop Avenue, adjacent to Kings Park, and Tydeman Road to serve the North Wharf area at Fremantle.

The Commonwealth games in 1962 resulted in new roads to serve Perry Lakes and the upgrading of Perth Airport led to the construction of Brearley Avenue.

The Standard Gauge Rail Project in the late sixties required new rail bridges at Great Eastern Highway, South Guildford and Welshpool Road, Wattle Grove.

The increasing traffic demand saw the removal of the roundabout at the Victoria Park end of the Causeway and its replacement with a modern traffic interchange.

At Bassendean, Guildford Road was realigned and dual carriageways constructed to provide a bypass of the town centre and to remove a notorious bend.

A second carriageway was constructed on Welshpool Road between the foot of Lesmurdie Hill and Crystal Brook Road to improve passing opportunity and safety. Slow vehicles were previously a serious problem.

During 1976, the Department was involved in the construction of Hayman Road and Kent Street in the

vicinity of the Western Australian Institute of Technology.

Some of the projects of this type are on roads under local authority control and in some of these instances, the funding of the projects was shared with the local authority and possibly a developer.

OTHER SERVICES

The Department is involved in providing a service to road users in several other fields which have developed markedly in the last 25 years.

Traffic Control Signals

At the time that the Narrows Bridge was opened in 1959 there were 39 traffic control signs in operation. Today there are over 400. In this time equipment has changed markedly and now controllers incorporate micro processors which make it possible to program signals to operate in a multi phase mode.

A recent innovation has been the advent of PACTS a system whereby signals along arterial routes are linked to greatly improve the chances of traffic travelling along the route receiving successive green lights. Currently over 40 sites in the City Centre, Shepperton Road/Albany Highway, Leach Highway and Scarborough Beach Road, Innaloo are connected to this system which is controlled by a single central computer.

Emergency Telephones

Recently emergency telephones have been installed over the full length of the Mitchell and Kwinana Freeways at intervals of 1 km. When first opened the Kwinana Freeway between the Narrows and Canning Bridges was equipped with emergency phones. However, these were taken out of the service because of the difficulty in maintaining them in a reliable condition. The new phones which were developed in New South Wales are much more resistant to the ravages of the elements and vandals.

Cycle Facilities

In recent years, there has been a growing interest in cycling in Perth. Following the widening of the Kwinana Freeway between the Narrows Bridge and Canning Bridge and its extension southwards, a cycleway was constructed along the foreshore between the Narrows Bridge and Cranford Avenue. This was done with the idea of providing access for recreational traffic along the river foreshore and it was planned that it would be used by both pedestrians and cyclists. The facility has proved immensely popular and improvements have been suggested by users to enhance its use for commuting cyclists working in the City.

In association with local authorities, an extension of the route northwards along the Mitchel Freeway is currently in progress. The Department is spending a considerable sum of money principally on structures associated with freeway works to ensure that cyclists can move parallel to the freeway without conflicting with the arterial traffic. Where necessary to provide continuity of the route, the facility is being constructed within the freeway reserve.

THE ENVIRONMENT

In the Metropolitan area, major roadworks follow routes laid down in the Metropolitan Region Scheme. Particularly in the case of the Mitchell Freeway, the alignment has followed a series of swamps which ordinarily could be expected to cause some controversy because of the rapid disappearance of wetlands in the Metropolitan area. In this case, the wetlands have been degraded for one reason or another and no particular difficulties were encountered.

Major projects undertaken by the Department are the subject of environmental examination before works proceed. Where items with particular significance are identified, action is taken to minimise the effect. There is, however, in most cases little scope to vary an alignment reserved in the Region Scheme because of the extent to which surrounding development has occurred.

Surveys have been undertaken in the major regional reserves to discover whether any Aboriginal sites of significance occur. One such site of particular interest was discovered on the alignment of the Roe Highway on the banks of the Helena River where evidence of occupation by man dating back for about 30,000 years was found.

In an attempt to offset the effects of major road construction, the Department is making a considerable effort to landscape the works immediately after construction. When the Kwinana Freeway was first built, comparatively little effort was made in this area and because of the exposed conditions, there were few plants that grew satisfactorily. In contrast, much greater effort was applied in the Narrows Interchange area. Many mature trees were planted and extensive areas were grassed and reticulated, but there was limited success with the establishment of shrubs, in some instances due to the exposure and others because of the poor soil.

Particular care has been taken in more recent works to preserve the topsoil as far as possible and to spread it over newly completed earthworks to encourage regeneration of naturally occurring vegetation and also to provide a better medium for the growth of introduced species. The southern extension of Kwinana Freeway highlights work of this type.

Recent jobs have been the subject of very heavy plantings of small trees and shrubs in tubes.

Until recent water shortages extensive use of reticulation was envisaged. Plant species selection and techniques of propagating plants under dry conditions are still evolving.

THE FUTURE

It would be of interest to postulate what further progress might be seen onthe north/south freeway route and the rest of Perth's major road system by say the turn of the century. What is actually achieved, of course, would depend upon the funds that are made available and on the growth that in fact does take place in different parts of the City because traffic demand plays a major part in the decision to build particular projects.

Narrows Bridge and Immediate Approaches

An improvement of growing importance to the existing freeway system is the provision of additional capacity at the Narrows Bridge to meet predicted traffic growth. It has been suggested from time to time that a duplicate bridge should be built. However, unless the approaches of the Kwinana and Mitchell Freeways are significantly upgraded, a duplicate bridge would provide more capacity than is justified. A more practical and appropriate solution would be to widen the existing bridge. Such a project could provide sufficient width across the Swan River to enable the existing roads to function without the existing constriction at the bridge site. This solution should cope with increasing traffic for many years and would provide capacity on the bridge that is in balance with the adjacent freeway system

Mitchell Freeway

Currently, work is under way to extend the freeway northwards to Warwick Road and this work should be completed by mid 1986. Following the Govenment's decision to construct a Marina in the vicinity of Sorrento, it has been decided to continue these freeway works to Hepburn Avenue. The completion of this will provide direct access to the Marina site for the anticipated traffic that will result during the America's Cup period. Following a submission from the Wanneroo Shire Council and the Joondalup Development Corporation, proposals are being examined to extend the freeway northwards to Joondalup Drive. Beyond the connection to Joondalup Drive, it seems unlikely that there will be any further extensions northwards for some considerable time.

An addition planned for completion in about four years is the construction of on and off ramps at Wellington Street to the freeway north. This will provide improved access to the City and reduce the pressure on existing railway crossing points.

It is likely that further work will become necessary on the Mitchell Freeway to increase its capacity northwards and from Leederville. Forward planning has allowed for this to be achieved by the duplication of the existing road between Loftus and MacDonald Streets. North of MacDonald Street, additional capacity has been allowed for in the design by providing additional traffic lanes in each direction.

Kwinana Freeway

The Metropolitan Region Scheme currently shows the Kwinana Freeway terminating at Forrest Road. The Metropolitan Region Planning Authority is currently investigating a route to establish a reservation southwards towards Mandurah. Completion of this planning work will define the future land required for the road so that construction works can follow as the need arises. An extension of the freeway south to Forrest Road could well be considered as the next stage.

The Major Road System

The most recent years have seen considerable progress with the development of the road system in the Control Access Highway reserves provided in the Metropolitan Region Scheme and it is expected that this progress will be continued. A number of major projects have already been committed. In the short term, the following projects will be undertaken:

- Work will continue on the Beechboro—Gosnells Highway to complete the link across the Swan River, including interchanges at Great Eastern Highway and Guildford Road, during 1987. This will provide a continuous roadway from Gosnells to Morley Drive and thus open up a major north-south route to the east of the city.

- Roe Highway will be extended northwards from Great Eastern Highway to Great Northern Highway during 1986 and 1987. It will then be extended southwards from the Beechboro-Gosnells Highway to Welshpool Road. This complements work on the Beechboro-Gosnells Highway.

- Redcliffe-Bushmead Highway will be completed between Great Eastern Highway and Roe Highway in 1986 and assist bypassing traffic on the Guildford-Midland Road.

- Work will accelerate in 1986/87 on the construction of the Burswood Bridge to provide a connection between Great Eastern Highway and the Hamilton Interchange. This work will take several years and will involve the development of Aberdeen and Newcastle Streets as a one-way pair.

- The southern approach from Leach Highway (High Road) to the Stirling Bridge will be constructed during 1985.

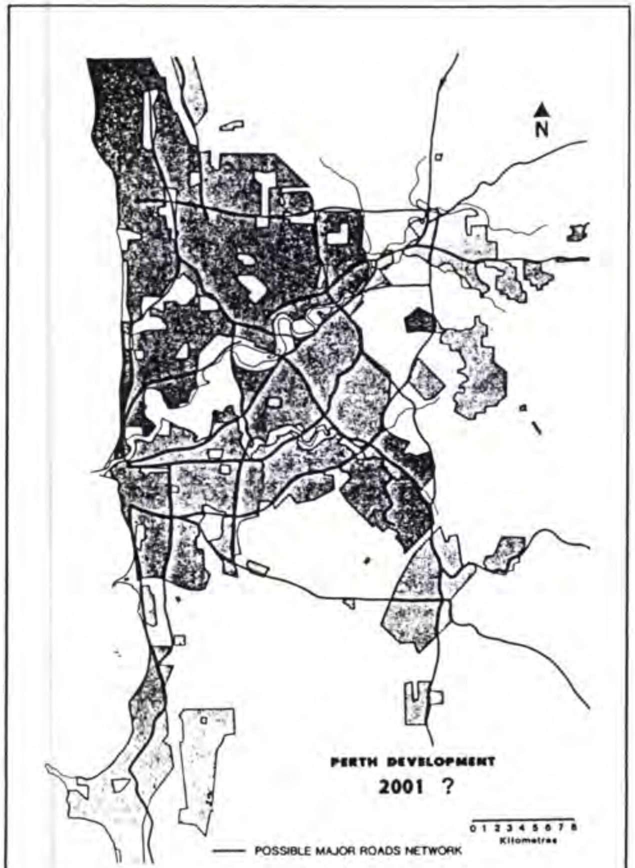
With the completion of these projects, it is anticipated that work could continue to the further development of a primary road network shown in the Region Scheme. Continuation of Roe Highway could proceed from Welshpool Road through to South Street and ultimately extend towards Fremantle as outlined in the planning scheme. The progressive development of the North Perimeter Highway will be seen from Great Northern Highway through to the Mitchell Freeway. When combined with the work already in hand, these two routes would provide an outer circular ring road for the metropolitan region. While major works of this nature

are in progress, traffic on the existing road system would continue to be carefully monitored to evaluate the need for local improvements. These improvements could take the form of additional traffic lanes, grade separation or works of a lesser nature which may be necessary to improve the efficiency of the road system.

A number of road proposals have proved to be extremely contentious in the past and are currently the subject of consideration by Government or are awaiting completion of planning studies. Examples of such projects are the Spencer-Manning Link to provide relief to Albany Highway, the Western Suburbs Highway and the Midland Western Link Road. Whether projects are included and if so their extent in such cases will of course depend upon the outcome of the studies.

The ability to commit expenditure on the projects listed above and to suggest that works will be undertaken on others is only possible because of the extent of planning that has been undertaken in Perth over the last thirty years. Corridors have been protected and land acquired for many of these projects due to the foresight over that period.

Twenty-five years ago the opening of the Narrows Bridge provided the keystone onto which a modern road system has been developed for the City of Perth. The challenge thrown out by the planners of the 50's has been acted upon and the Main Roads Department has been able to construct a major road system that is now the envy of most other comparable cities in the world. The road network that has been developed can continue to expand to enable the transport needs of a rapidly growing city to be met in a safe and efficient manner.



APPENDIX

Many people, both within and outside the Main Roads Department have had a deep involvement in the planning and design of Perth's Freeway system since the Hon John T. Tonkin, MLA, took the proposal to Cabinet to build the Narrows Bridge and its Kwinana Freeway approaches.

Ministers responsible for the Department in that period have included:

Hon John T. Tonkin, A.C., M.L.A.
Hon Gerald P. Wild, A.M., M.B.E., E.D., M.L.A.
Hon Sir Ross Hutchinson, D.F.C., M.L.A.
Hon C.J. Jamieson, M.L.A.
Hon R.J. O'Connor, M.L.A.
Hon D.J. Wordsworth, M.L.C.
Hon E.C. Rushton, M.L.A.
Hon J.F. Grill, M.L.A.

Commissioners of Main Roads since the formation of the Department have been:

Mr Edward Tindale	(1926—1941)
Mr J.W. Young	(1941—1953)
Mr J.D. Leach	(1953—1964)
Mr J.J.G. Punch	(1964—1965)
Mr D.H. Aitken	(1965—present)